THE COURT OF APPEAL OF THE REPUBLIC OF SINGAPORE

[2023] SGCA 5

Civil Appeal No 41 of 2020

Between

IIa Technologies Pte Ltd

… *Appellant*

And

Element Six Technologies Ltd

… *Respondent*

In the matter of HC/S 26/2016

Between

Element Six Technologies Ltd

… *Plaintiff*

And

IIa Technologies Pte Ltd

… *Defendant*

JUDGMENT

[Intellectual Property — Patents and Inventions — Claim Construction]
[Intellectual Property — Patents and Inventions — Invalidity — Insufficiency]
[Intellectual Property — Patents and Inventions — Patent specification]

[Intellectual Property — Patents and Inventions — Revocation]

IIa Technologies Pte Ltd
v
Element Six Technologies Ltd

[2023] SGCA 5

Court of Appeal — Civil Appeal No 41 of 2020
Sundaresh Menon CJ, Judith Prakash JA, Steven Chong JA
2–4 August 2021, 20, 24–25 January 2022

17 February 2023 Judgment reserved.

Sundaresh Menon CJ (delivering the judgment of the court):

1 The parties are competitors in the production of synthetic diamonds grown using chemical vapour deposition ("CVD"). At its simplest, under this process, a substrate (which is also known as a diamond seed) is placed in a reactor containing a mixture of gases, including methane (CH_4) and hydrogen (H_2). Upon exposure to high energy, the gaseous molecules break up into plasma containing carbon (or "C") atoms. The C atoms are then deposited on the substrate, growing the synthetic diamond layer by layer.[1]

2 The appellant, a company incorporated in Singapore, claims to be a major manufacturer of CVD diamonds and has a diamond-growing facility in

[1] Primer at para 3(b).

Singapore.[2] The respondent, a company incorporated in the United Kingdom, is part of the Element Six Group. The Element Six Group is a member of the De Beers Group, which is itself a subsidiary of the Anglo American PLC.[3] The De Beers Group is an international diamond business and a diamond producer, while the Anglo American PLC is a global mining company. According to the respondent, the Element Six Group is a global leader in the design, development and production of "synthetic diamond supermaterials".[4] The respondent claims that its CVD diamonds have potential technical applications in various industries, including optics, semiconductors and sensors.[5]

3 In HC/S 26/2016 ("Suit 26"), the respondent claimed that the appellant had infringed two of its patents registered in Singapore, Singapore Patent No 115872 ("SG 872") and Singapore Patent No 110508 ("SG 508"). To prove infringement, the respondent relied on three samples of diamonds, which were labelled Sample 2, Sample 3 and Sample 4 (collectively, the "Samples"), allegedly purchased from the appellant or the appellant's related entities or distributors. It claimed that the Samples were made from CVD diamond material synthesised by the appellant and that the appellant must have used the method of growth taught in Claims 62 to 71 of SG 872.[6] In its defence, the appellant denied infringing the patents and, in any case, disputed their validity.[7] The appellant also sought the revocation of both patents by way of a

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2 See Appellant's Case ("AC") at para 2; Mr Meta Visha Jatin's AEIC at para 17 (III(B01) ROA 7).

3 Ms Susan Jane Fletcher Watts' AEIC at paras 4–5 (III(A1) ROA 7–8).

4 Ms Susan Jane Fletcher Watts' AEIC at para 5 (III(A1) ROA 8).

5 Ms Susan Jane Fletcher Watts' AEIC at para 7(b) (III(A1) ROA 9).

6 Particulars of Infringement (Amendment No 2) at para 4 (II(1) ROA 35–44).

7 Defence & Counterclaim (Amendment No 6) at paras 5–6 (II(1) ROA 26 and 69).

counterclaim.[8] On 7 February 2020, the trial judge (the "Judge") declared that SG 508 was invalid and revoked it on the basis that it was neither novel nor inventive (*Element Six Technologies Ltd v IIa Technologies Pte Ltd* [2020] SGHC 26 ("*Judgment*") at [291] and [478(d)]–[478(e)]). This was a complete defence to the respondent's claim for infringement in so far as SG 508 was concerned (*Judgment* at [416]). However, the Judge found that SG 872 was valid and declined to revoke it. She further found that the appellant had infringed specific claims in SG 872. In this appeal, although both parties proceeded on the basis that Claims 1ii), 1iii), 57, 58 and 62 of SG 872 were infringed,[9] it is not entirely clear whether the Judge confined her finding of infringement to specific limbs of Claim 1 (*Judgment* at [9], [416], [443], [454], [456] and [478(a)]). But this difficulty need not detain us. Even taking Claims 1ii) and 1iii) as the point of departure for our analysis on invalidity, our conclusions affect the *entirety* of Claim 1 and the outcome of the appeal will not change even if the Judge had found the whole of Claim 1 to be infringed.

4 On 6 March 2020, the appellant filed CA/CA 41/2020 ("CA 41") appealing against the Judge's rejection of its defence that SG 872 is invalid and its counterclaim to revoke the entirety of SG 872. It also challenged the Judge's finding that Claims 1ii), 1iii), 57, 58 and 62 in SG 872 had been infringed.[10] The respondent has not cross-appealed against the Judge's findings in respect of SG 508.

5 The Judge delivered her decision on costs (the "Judge's Costs Decision") on 30 March 2020, holding that the respondent was entitled to the

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8 Defence & Counterclaim (Amendment No 6) at (3) and (7) (II(1) ROA 73).

9 AC at para 3; Respondent's Case ("RC") at para 5(e).

10 See Notice of Appeal in CA/CA 41/2020 dated 6 March 2020; AC at para 3.

costs of Suit 26 on a standard basis as well as costs of $3,000 (all in) for the costs hearing which took place on 30 March 2020. On 25 June 2020, the appellant filed CA/CA 96/2020 ("CA 96") appealing against the entirety of the Judge's Costs Decision.

6 This judgment deals only with CA 41.

Background

Procedural history and case management on appeal

7 On 17 August 2020, the appellant filed CA/SUM 87/2020 ("SUM 87"), seeking leave to admit further evidence from Dr Werner Kaminsky ("Dr Kaminsky", the appellant's expert) for the purpose of challenging the evidence of Dr Anthony Michael Glazer ("Dr Glazer", the respondent's expert) on his gap theory ("Gap Theory") (see [36] below for relevance of the Gap Theory in this appeal). We dismissed SUM 87 on 16 September 2020.

8 As appears below, the technical background to SG 872 – including the physical properties of diamonds, how SG 872 seeks to enhance the quality of CVD diamonds grown and the measurement or evaluation of the improvement brought about by SG 872 – is highly complex. The following steps greatly assisted us in coming to grips with the difficult material:

(a) On 19 April 2021, we directed the parties to prepare a "Primer" (with a 50-page limit) setting out their points of agreement and divergence on topics including the common general knowledge (such as different methods of growing diamonds and types of defects in diamonds), the state of the art (including other patents) and the inventive concept of SG 872.

(b) We also convened a "Technology Tutorial" that was conducted on 2, 3 and 4 August 2021. Each party was allowed to nominate up to two presenters from among their expert witnesses to address these topics as well as provide an introduction to SG 872 and the Metripol system.[11] The parties filed and exchanged Powerpoint slide decks prepared by their presenters seven days before the Technology Tutorial.

In the section that follows, we outline the salient aspects of the background to SG 872 as presented in the Primer and Technical Tutorial, which will set the context for our analysis of its validity.

9 Following the Technology Tutorial, CA 41 was heard over three half-day hearings on 20, 24 and 25 January 2022.

10 Subsequently, on 14 September 2022, we wrote to the parties to clarify whether each product claim in SG 872 covers a class of products as opposed to an individual product. The significance of this point, as well as of the parties' responses on 21 September 2022, will become clear when we analyse whether SG 872 should be revoked in its entirety.

Technical background

11 We first set out the technical background to SG 872. As we later elaborate, SG 872 discloses a new single crystal CVD diamond material, at least 0.5mm in thickness, which possesses one or more properties stated in the patent. One such property is low "optical birefringence" (henceforth referred to as "birefringence"). It is the respondent's case that without the new CVD growth

[11] Court's letter dated 19 April 2021 at para 5, read with Appellant's letter dated 13 April 2021, p 4 s/n 4.

process taught within SG 872, the single crystal CVD diamond material manufactured would not display the properties defined in the product claims of SG 872. It is said that these properties are indicative of a high-quality diamond.[12]

Synthetic diamonds and CVD

12 Diamonds are a form of solid C (meaning carbon) in which each C atom is bonded to four neighbouring C atoms to form a tetrahedral structure. Many of these tetrahedral structures come together to form a diamond lattice. A "single crystal" diamond, which is claimed in SG 872, is one in which the crystal lattice of the entire sample is continuous and unbroken. In contrast, a polycrystalline diamond consists of many single crystals.[13]

13 Diamonds may form naturally within the Earth's crust or be manufactured in a laboratory.[14] CVD is one of the main ways of manufacturing diamonds, the other of which involves applying high-pressure-high-temperature ("HPHT") on a C source mixed with a catalyst.[15]

Impurities, defects and strain in diamonds

14 In reality, no diamond (natural or man-made) is an array of *equally* spaced atoms which are purely C. Diamonds will contain impurities and defects. We make this point to provide context to what the respondent/patentee sought to achieve through the new growth processes taught in SG 872. As will become clear, the type and extent of defects in a diamond bear on its physical properties,

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12 RC at para 12.

13 RC at para 13; Dr Mark Edward Newton's 1st Report ("Newton-1") at p 34 (I RSCB 133); Primer at para 80; Transcript, 3 August 2021, p 20:26-27 (Dr Newton).

14 Primer at paras 2–3.

15 Primer at para 3(a).

such as its strength,[16] and hence its potential industrial use(s) and application(s). The respondent sought to produce CVD single crystal diamonds with certain qualities which were required for specific industrial applications. Allegedly, such diamonds could only be produced using the processes claimed in SG 872. What follows elaborates on the nature of defects or impurities arising in diamonds and the relationship between these imperfections and a diamond's physical properties.

15 *Impurities* refer to non-C atoms bonded into the diamond's lattice structure. Common impurities include nitrogen (N_2) and boron. The concentration of nitrogen and boron is expressed in parts *per* million ("ppm") or parts *per* billion ("ppb").[17] Based on its purity, a diamond can be categorised into two main types: Type I and Type II. These can be further sub-divided into Types Ia, Ib, IIa and IIb. Type I diamonds contain relatively large amounts of nitrogen – up to 0.3% (5ppm to ~ 3000ppm). Most of the nitrogen atoms in Type Ia diamonds are found in clusters, but this is not the case in Type Ib diamonds.[18] Type II diamonds contain nitrogen below 5ppm. The only impurity in Type IIa diamonds is nitrogen, whereas impurities in Type IIb diamonds consist of nitrogen and boron.[19]

16 When impurities (meaning non-C atoms) enter the diamond's structure, a point *defect* is created in the lattice structure.[20] Extended defects, on the other hand, are structural defects caused by disruptions to the diamond lattice that

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16 See, *eg*, Primer at para 52.

17 Primer at para 4.

18 Primer at para 7.

19 Primer at para 8.

20 Primer at para 18.

extend across the crystal.[21] One example of an extended defect is a stacking fault, which occurs where the relative positioning of two adjacent layers (or planes) of crystal structure does not conform with the rest of the crystal:

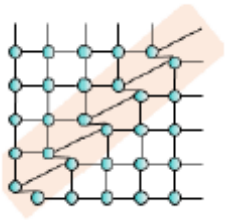

Figure 1: Diagram depicting stacking faults

Another type of extended defect is a dislocation. Dislocations occur where there are atoms out of position in the crystal structure that, among other things, form an extra line of atoms within the structure (that is, an edge dislocation):[22]

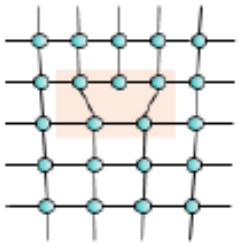

Figure 2: Diagram depicting dislocations

17 Extended defects can be visualised using X-ray topography images where stacking faults appear as dark planes (Figure 3) and dislocations appear as dark lines (Figure 4). Thicker and relatively darker lines show bundles of dislocations:[23]

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21 Primer at para 19.

22 Primer at para 19.

23 IV ACB 164.

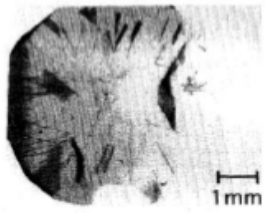

Figure 3: 2-D X-ray topography of IIa HPHT diamond showing stacking faults (black areas) (from H Sumiya et al*, "Crystalline perfection of high purity synthetic diamond crystal" (1997) 178 Journal of Crystal Growth 485 at 490)*

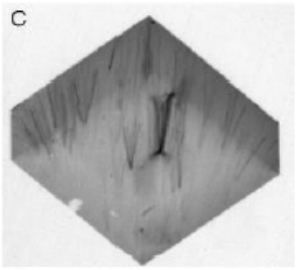

Figure 4: X-ray topography of CVD diamond showing dislocations as black lines (from I Friel et al*, "Control of surface and bulk crystalline quality in single crystal diamond grown by chemical vapour deposition" (2009) 18 Diamond & Related Materials 808 at 812)*

18 Dislocations cause strain, or distortion to the position of atoms, in the diamond structure.[24] The strain extends across the full length of the dislocation, which typically runs all the way across the diamond.[25] Strain weakens the chemical bonds, which then can be broken with lower energy. This reduces the strength of the diamond to withstand external pressure.[26] According to Dr Christoph Erwin Nebel ("Dr Nebel"), the appellant's principal expert,[27] if there is strain, electrons between the atoms are no longer homogenously distributed, resulting in an electric field that may interact with light and increase

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24 See Transcript, 2 August 2021, p 12:6–7.

25 Primer at paras 22 and 40.

26 Primer at para 22.

27 AC at para 11.

birefringence in the diamond (a property we explore in some detail at [20]–[27] below).[28]

19 Dislocation density refers to the number of dislocations *per* square cm or mm of surface. Dislocations extend across the diamond like a line (hence, "line defects") and terminate only on the surface:[29]

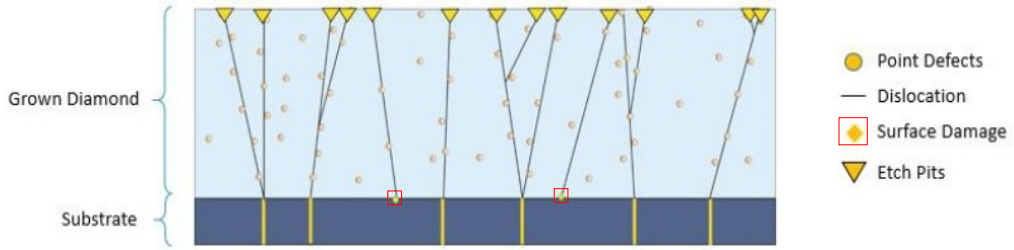

Figure 5: Dislocations originate from the substrate surface and propagate into the diamond. They can multiply during growth and become decorated with nitrogen.

Dislocation termination points reveal themselves as etch pits. An optical evaluation of the number of etch pits across the surface area of the diamond will reveal its dislocation density:

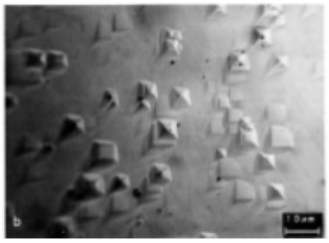

Figure 6: Etch pits on diamond with dislocation density of 3300/mm^2

[28] Transcript, 2 August 2021, p 12:3–11.

[29] Primer at para 29.

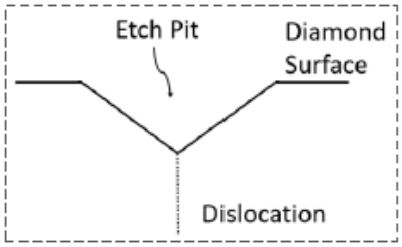

Figure 7: Cross-section of an etch pit

Birefringence

20 Birefringence is a physical property of diamonds relevant to the key claims in SG 872. We shall therefore explore this concept in some detail.

21 Birefringence, stated generally, is related to how light interacts with a certain object. Light is made of waves of electric and magnetic fields. These waves oscillate in all directions perpendicular to the direction of the transmission of light. The distance travelled when an electromagnetic wave goes through one full oscillation cycle is called wavelength, which is denoted by λ. The wavelength of light determines its colour.[30]

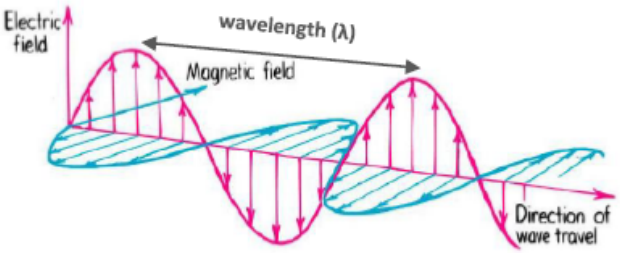

Figure 8: Diagram of a light wave in terms of its electro-magnetic field

22 While normal light consists of electric fields oscillating in all directions in the plane perpendicular to the direction of propagation, a polariser filter may

[30] Primer at para 33.

be used to only allow light containing electric fields oscillating in a single direction to pass through. "Polarised light" therefore has only one direction of oscillation.[31]

23 The atomic arrangement in a material affects the speed at which light travels through it. The speed of light in an optical material is determined by the material's refractive index. The denser the material, the higher its refractive index and the slower that light travels through it.[32]

24 Where the internal structure of the crystalline material is perfect, in that it has no impurities or defects, the crystalline material is highly symmetrical. Such material is referred to as isotropic. In isotropic materials, the refractive index is the same in all directions. This means that light passes through an isotropic crystal at a single velocity.

25 But for anisotropic materials, the refractive index may vary in different directions. Although a diamond may theoretically be isotropic due to its highly symmetrical uniform lattice of C atoms, in reality, diamonds are anisotropic due to strain caused by dislocations.[33] When polarised light is passed through a diamond with strain, the light splits into two relevant components which travel at different velocities. One component travels faster along the path in the material with the smallest refractive index (n") and the other travels slower along the path in the material with the largest refractive index (n'). The difference between the smallest and largest available refractive index is called

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31 Primer at para 35.

32 Primer at para 36.

33 Primer at para 37.

birefringence ($\Delta n = |n' - n''|$).[34] In other words, strain in diamonds results in birefringence.[35]

26 The gap between the faster and slower components of light when they emerge out of the material is defined as the optical retardation (also referred to as "retardation" or "path difference"). Light of any wavelength which passes through a sample of an anisotropic material having birefringence Δn, where the sample has a thickness of "L", will display retardation of $L \cdot \Delta n$. Dr Nebel depicted birefringence and retardation as follows:[36]

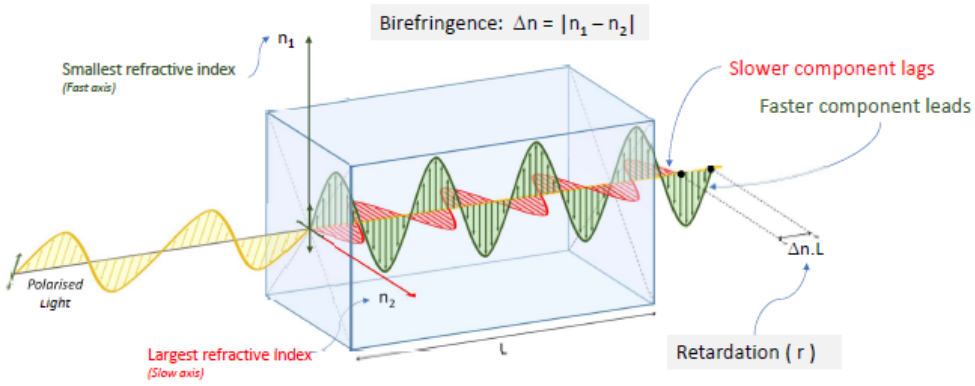

Figure 9: Diagram showing how the variation in the refractive index causes birefringence

27 For light of a particular wavelength (or λ), retardation can also be represented as phase shift "δ":[37]

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34 Primer at para 38.

35 Primer at para 40; Transcript, 3 August 2021, p 29 (Dr Newton).

36 Dr Christoph Erwin Nebel's technical tutorial ("Dr Nebel's technical tutorial"), slide 15.

37 Primer at para 39.

$$\delta = \frac{2\,\pi}{\lambda}\,\Delta n.L$$

Dr Nebel represented the components of the above equation, using the following diagrams of light components that have split up when passing through an object:[38]

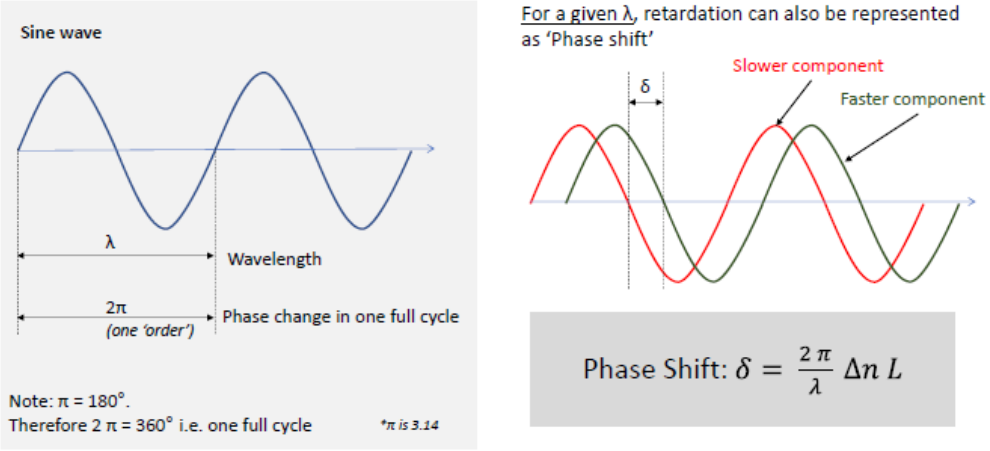

Figure 10: Diagrammatic representation of retardation as a "phase shift"

Salient features of SG 872

28 This appeal concerns SG 872, which was filed on 20 November 2003. In essence, the patent covers a new optical quality synthetic single crystal CVD diamond material and the method for its production.[39] The patent contains both product and process claims. A product claim is one which "asserts exclusive rights over a new thing, such as new machines, items or articles of manufacture and composition of matter". Although the patentee may describe only one use of his invention, he has the right to stop others from using it for other purposes (Susanna H S Leong, *Intellectual Property Law of Singapore* (Academy

38 Dr Nebel's technical tutorial, slide 17.

39 Statement of Claim (Amendment No 2) at para 2 (II(1) ROA 27).

Publishing, 2013) ("*Susanna Leong*") at para 18.002). We will henceforth refer to a diamond falling within any of the product claims in SG 872 as an "SG 872 Diamond". On the other hand, "a process claim covers a new activity such as a process or method of manufacturing and logically, in a method or process claim, it is the process used and not the end result which must be new to justify patentability." (*Susanna Leong* at para 18.003).

29 The pivotal product claim, which all subsequent claims refer back to, is Claim 1:

> 1. A CVD single crystal diamond material which shows at least one of the following characteristics, when measured at room temperature (nominally 20°C):
>
> i) a high optical homogeneity, with the transmitted wavefront differing from the expected geometrical wavefront during transmission through diamond of a specified thickness of at least 0.5 mm, processed to an appropriate flatness and measured over a specified area of at least 1.3 mm x 1.3 mm, by less than 2 fringes, where 1 fringe corresponds to a difference in optical path length equal to ½ of the measurement wavelength of 633 nm;
>
> ii) a low optical birefringence, indicative of low strain, such that in a sample of a specified thickness of at least 0.5 mm and measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, the modulus of the sine of the phase shift, $|\sin \delta|$, for at least 98% of the analysed area of the sample remains in first order (δ does not exceed $\pi/2$) and the $|\sin \delta|$ does not exceed 0.9;
>
> iii) a low optical birefringence, indicative of low strain, such that in a sample of a specified thickness of at least 0.5 mm and measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, for 100% of the area analysed, the sample remains in first order (δ does not exceed $\pi/2$), and the maximum value of $\Delta n_{[average]}$, the average value of the difference between the refractive index for light polarised parallel to the slow and fast axes averaged over the sample thickness, does not exceed 1.5×10^{-4};
>
> iv) an effective refractive index in a sample of specified thickness of at least 0.5 mm, measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, which has a value of 2.3964 to within an accuracy of +/-0.002;

> v) combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of an etalon of a specified thickness of at least 0.5 mm and measured using a laser beam with a wavelength near 1.55 μm and a nominal diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, it exhibits a free spectral range (FSR) which, when measured at different positions over the plate, varies by less than 5×10^{-3} cm^{-1};
>
> vi) a combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of a Fabry-Perot solid etalon of a specified thickness of at least 0.5 mm, and measured using a laser beam with a wavelength near 1.55 μm and a nominal diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, and which has no coatings applied to the optically prepared surfaces, it exhibits when measured at different positions over the plate a contrast ratio exceeding 1.5;
>
> vii) a combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of an etalon of a specified thickness of at least 0.5 mm, and measured using a laser beam with a wavelength near 1.55 μm and a diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, it exhibits an insertion loss not exceeding 3 dB;
>
> viii) a variation in refractive index over a volume of interest, said volume comprising a layer of a specified thickness of at least 0.5 mm, measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, which is less than 0.002.

30 Single crystal CVD diamond material falling within Claim 1 has low strain and exhibits at least one of the optical properties defined in the eight limbs of Claim 1.[40] Two of these limbs, limbs ii) and iii), assume significance in this dispute. Following the terminology used by the parties and the Judge, we will refer to these two limbs as "Claim 1ii)" and "Claim 1iii)" respectively. As the respondent pleads that Claims 1ii) and 1iii) were infringed (see *Judgment* at [417]),[41] we elaborate on these. Claims 1ii) and 1iii) assert a monopoly over

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40 Primer at para 140.

41 Particulars of Infringement (Amendment No 2) dated 26 October 2018 at para 1 (II(1) ROA 31–32).

single crystal CVD diamond material with low birefringence. Low birefringence is quantified in Claim 1ii) as a sample (a) remaining in the first order (δ does not exceed $\frac{\pi}{2}$); and (b) with the modulus of the sine of the phase shift (that is, $|\sin \delta|$) not exceeding 0.9. Low birefringence is quantified in Claim 1iii) as a sample (a) remaining in the first order (δ does not exceed $\frac{\pi}{2}$); and (b) with the maximum value of $\Delta n_{[average]}$ (that is, the average birefringence across the thickness of the sample) not exceeding 1.5×10^{-4}.

31 We highlight four key points pertaining to Claims 1ii) and 1iii) which the parties do not dispute. First, the term "first order" for the purposes of SG 872 (and Claims 1ii) and 1iii) in particular) has been defined in a specific way. The parties' experts, when explaining certain technical concepts (see above at [27] and below at [191]),[42] referred to each "order" as a multiple of 2π, with "first order" covering a range of values where δ does not exceed 2π (or again, expressed as an equation, $\delta \leq 2\pi$). However, SG 872 defines "first order" in a much more limited sense, namely, where δ does not exceed $\frac{\pi}{2}$ (or again, expressed as an equation, $\delta \leq \frac{\pi}{2}$) (the "SG 872 First Order").[43]

32 Second, it is undisputed that SG 872 directs the person skilled in the art ("PSA") to use a Deltascan (which has been renamed as the Metripol since 2001)[44] or a "similar instrument with similar resolution" to determine the value of $|\sin \delta|$ and $\Delta n_{[average]}$.[45] The Metripol is an optical microscope-based imaging

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42 See also Primer at para 47.

43 Primer at paras 155–156; see Bundle of Materials dated 28 June 2021 ("BOM") at p 363.

44 Primer at para 146; Dr Nebel's technical tutorial, slide 66.

45 BOM at pp 302 and 308. Primer at para 146.

system,[46] which was developed by Dr Glazer (the respondent's expert), Dr Kaminsky (the appellant's expert), and Dr Morten Geday ("Dr Geday") (the appellant's witness) in or around 1995. The Metripol has a polariser that rotates in fixed multiples of different angles (for example, by 30^{o}, 60^{o}, 90^{o}) ("Rotation Angles"). At each angle, polarised light passes through the specimen and is captured by a camera. The Metripol calculates the intensities of light received by the camera at different Rotation Angles, and thereafter computes $|\sin \delta|$, which is a function of δ.

33 It will be recalled that δ is the optical retardation of light of a particular wavelength that passes through a material, and is related to the birefringence of the material by the formula set out at [27] above.[47] As appears from the three graphs below (in particular, the green arrows in graphs (b) and (c)), $|\sin \delta|$ is the amplitude of a sinusoidal curve (meaning half the distance from the highest point of the curve to its lowest point). This sinusoidal curve is derived by plotting the intensity of polarised light that passes through the diamond specimen on the y-axis, against the polariser's Rotation Angle on the x-axis.[48] Depending on whether and the extent to which the intensity of light varies when the polariser is angled differently, $|\sin \delta|$ will assume a different value:[49]

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46 Primer at para 146.

47 Primer at para 150.

48 Primer at para 151.

49 Dr Nebel's technical tutorial, slide 68; see also Primer at para 151.

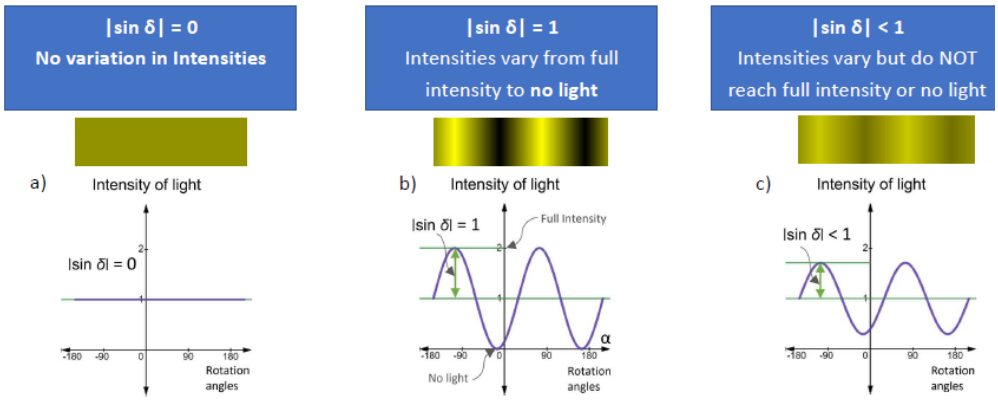

Figure 11: Graphs depicting the variation of intensities of light against the polariser's Rotation Angle

34 Third, after computing |sin δ|, the Metripol produces colour-coded images of the material, where the different colours represent different |sin δ| values at any place within the image (the "Metripol |sin δ| Map").[50] The Metripol is capable of refining the |sin δ| value at each pixel position in the Metripol |sin δ| Map.[51] An illustration of the Metripol |sin δ| Map can be found in the following diagram, taken from the respondent's Technology Tutorial slides:

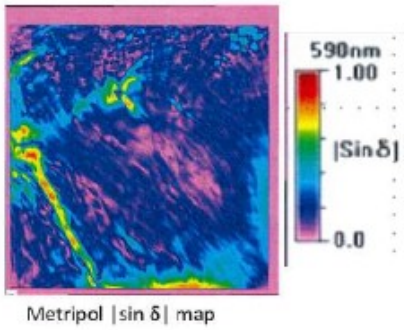

Figure 12: Illustration of a colour-coded image produced by the Metripol (that is, the Metripol |sin δ| Map)

50 Primer at para 147.

51 Primer at para 157.

The same Metripol |sin δ| Map can also be represented in greyscale. The patent specification of SG 872 states that the spatial variation of |sin δ| can be appreciated from these images.[52] The patent specification also states that for each sample, sets of |sin δ| images are to be recorded for analysis.[53]

35 Fourth, it is agreed between the parties that the Metripol data on its own does not tell the PSA whether the δ value of a diamond falls within the SG 872 First Order (the "Metripol Uncertainty Problem").[54] The Metripol does not calculate δ. As mentioned, it generates the value of |sin δ|.[55] However, each |sin δ| value corresponds to many δ values, and only one of these δ values lies within the SG 872 First Order.[56] From the |sin δ| value alone, the PSA ***cannot*** derive ***a*** corresponding δ value and will not know whether the δ value of a diamond is within or outside the SG 872 First Order. This point can be illustrated in Figure 13 below, where δ_1 is the value that lies within the SG 872 First Order:[57]

52 See BOM at p 330.

53 BOM at p 331.

54 Primer at paras 154–155.

55 Primer at para 152.

56 Primer at para 153 and Figure 44.

57 Primer at para 152.

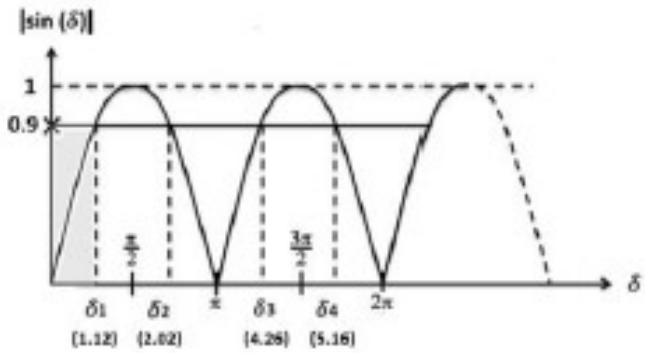

Figure 13: Graph showing that |sin δ| of 0.9 may indicate multiple possible values of δ

If the Metripol shows that the |sin δ| value of the diamond is 0.9, the corresponding δ value ***can*** be 1.12, 2.02, 4.26, 5.16, or any other higher value not reflected in Figure 13 above.[58] δ will only be within the SG 872 First Order if it has a value of 1.12, as that is the only value that does not exceed $\frac{\pi}{2}$ (see above at [31]). The rest of the values lie outside the SG 872 First Order. From this range of possible δ values, the PSA relying solely on the Metripol reading cannot determine *the* δ value of the diamond, and accordingly, cannot ascertain whether δ is within the SG 872 First Order.

36 In this appeal, as they did in the proceedings below, the parties diverge on the issue of whether the PSA knew of solutions to overcome the Metripol Uncertainty Problem at the relevant time. The thrust of the appellant's contention is that the PSA, faced with the Metripol Uncertainty Problem and with no knowledge of any workable solution at the relevant time, would not be able to determine whether the δ value of the diamond was within the SG 872 First Order and hence within the scope of the asserted monopoly. For this reason, the appellant contends that SG 872 is insufficient.[59] In turn, the

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58 Primer at para 153 and Figure 44.

59 AC at paras 151–211; Defendant's Closing Submissions in Second Tranche of Trial ("DCS2") at paras 307 and 311–347 (III(G5) ROA 149–151 and 152–169).

respondent's case is that the PSA would have no difficulty ascertaining that the δ value of the diamond was within the SG 872 First Order by using various methods, such as the Gap Theory proposed by Dr Glazer.[60] We will deal with this issue in our analysis later.

37 We now turn to Claim 62, the main process claim in SG 872 to which all other process claims in SG 872 refer. Claim 62 specifies a method of producing low-strain single crystal CVD diamond material that exhibits optical properties defined in the product claims in SG 872. Claim 62 states as follows:

> 62 A method of producing a CVD diamond material suitable for optical applications and according to any one of the preceding claims, which method includes the steps of:
>
> - providing a substrate substantially free of crystal defects,
> - providing a source gas,
> - dissociating the source gas to produce a synthesis atmosphere which contains 300 ppb to 5 ppm nitrogen, calculated as molecular nitrogen, and allowing homoepitaxial diamond growth on the surface which is substantially free of crystal defects
>
> wherein the surface damage of the substrate is minimised by including a plasma etch on the surface on which homoepitaxial diamond growth is to occur, whereby a density of defects at the surface of the substrate is such that surface etch features related to the defects is below $5 \times 10^3/mm^2$,
>
> wherein the level of nitrogen is controlled with an error of less than 300 ppb (as a molecular fraction of the total gas volume) or 10% of the target value in the case phase, whichever is the larger, and
>
> wherein the level of nitrogen is selected to be sufficient to prevent or reduce strain generating defects whilst being low enough to prevent or reduce deleterious absorptions and crystal quality degradation, thereby producing a CVD single crystal diamond material meeting the requirements of one or more of claims 1 to 61.

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60 RC at paras 175–194; Plaintiff's Closing Submissions in Second Tranche of Trial ("PCS2") at paras 898–906 (III(G3) ROA 130–134).

38 Certain terms relating to the growth process, which are referred to subsequently, call for further explanation. The "source gas" in the CVD chamber comprises several gases, including a "C" source which is typically methane (CH_4) and a source of atomic hydrogen which is typically hydrogen (H_2). The parties agree that other gases, such as an inert gas (like argon) and a dopant gas (like nitrogen, boron or phosphorous), a source of impurities which is used to affect the electrical or optical properties of a diamond, are also used depending on the desired characteristics of the CVD diamond.[61] Each input gas is controlled by a mass flow controller ("MFC"). The flow of gases across MFCs is measured as cubic centimetres of gas flowing through the MFC *per* minute (expressed as standard cubic centimetres *per* minute or "sccm"). The concentration of each gas is represented as a percentage, ppm or ppb.[62] As for the "plasma etch" performed on the substrate prior to the commencement of the CVD process, this involves "exposing the substrate to a plasma formed by hydrogen (H_2) and/or oxygen (O_2) at high temperature in a CVD chamber."[63] The specification of SG 872 states that such *in situ* plasma etching minimises the surface damage of the substrate.[64] We note, however, that the respondent disputes[65] whether the use of a plasma etch to achieve this effect is common general knowledge to a PSA (we will explain the concepts of common general knowledge and the PSA at [63]–[75] below).

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61 Newton-1 at para 236 (IIIA(24) ROA 171); Dr Newton's 2nd Report ("Newton-2") at para 155 (IIIA(56) ROA 74); Dr Nebel's 2nd Report ("Nebel-2") at para 117 (IIIB(62) ROA 63); Primer at para 96.

62 Primer at para 97.

63 Primer at para 92.

64 BOM at p 317.

65 RC at para 150.

39 The respondent claims that the production of low-strain single crystal CVD diamond material disclosed in Claims 1 to 61 and 72 to 78 was *not* possible prior to the discovery of the process in Claim 62.[66] The respondent argues that the growth process in Claim 62, specifically, the addition of 300ppb to 5ppm nitrogen to the synthesis atmosphere (the "Claim 62 Nitrogen Range"), is novel because it runs contrary to previous thinking that adding nitrogen to the synthesis atmosphere would have a deleterious effect on the quality of the diamond produced; nitrogen was regarded as an impurity.[67] As the Judge noted, the common general knowledge at the material time was that the addition of nitrogen would *increase* birefringence. The Claim 62 Nitrogen Range is therefore the inventive concept asserted in Claim 62 (see *Judgment* at [253]). We agree. According to the specification of SG 872, the Claim 62 Nitrogen Range is not too high because it accomplishes the aim of "prevent[ing] or reduc[ing] local strain generating defects whilst being low enough to prevent or reduce deleterious absorptions and crystal quality degradation."[68] Nor is the range too low, because, according to SG 872, "material grown under conditions with essentially no nitrogen, or less than 300ppb nitrogen has a comparatively higher level of local strain generating defects".[69] Dr Philippe Bergonzo ("Dr Bergonzo"), one of the respondent's experts, depicted the benefits of operating within the Claim 62 Nitrogen Range as follows (see the curve in black):[70]

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66 Transcript, 4 August 2021, p 38:11–20.

67 RC at para 18.

68 BOM at p 310.

69 BOM at p 312.

70 Dr Philippe Bergonzo's technical tutorial slides, slide 41.

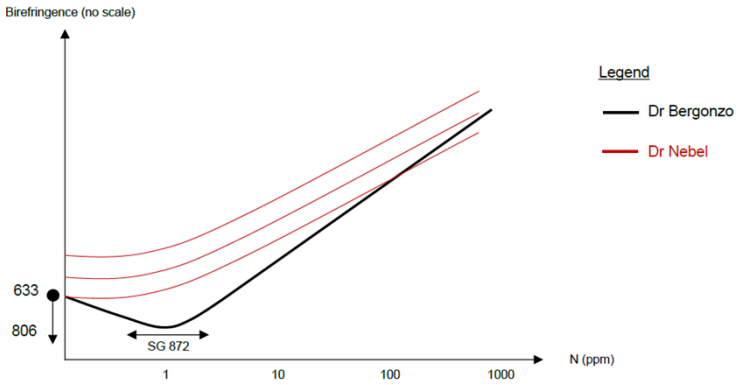

Figure 14: Graph depicting the benefits of operating in the Claim 62 Nitrogen Range

40 As against this, the appellant regards the purported benefits of using the Claim 62 Nitrogen Range as "illusory" and "false".[71] It questions why, in the 17 or so years since SG 872, not a single paper has been published discussing or evidencing this discovery. However, as we shall explain, even assuming that the purported benefits of the Claim 62 Nitrogen Range are scientifically true, there are other issues undermining the validity of the patent.

Decision below

41 Against the appellant's arguments to the contrary, the Judge held that Claims 1 and 62 of SG 872 were valid. For brevity, we will only summarise the Judge's reasons for rejecting the appellant's contentions on insufficiency, and only in so far as they are relevant to the determination of this appeal.

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[71] AC at paras 131–132.

42 The Judge observed that the appellant had relied on s 25(5) of the Patents Act (Cap 221, 2005 Rev Ed) ("Patents Act (2005 Rev Ed)"),[72] which provided that claims shall be "clear and concise" in s 25(5)(*b*). Citing this court's decision in *First Currency Choice Pte Ltd v Main-Line Corporate Holdings Ltd and another appeal* [2008] 1 SLR(R) 335 ("*First Currency Choice*") at [72], the Judge held that the requirement of clarity was not a ground for revocation under the Patents Act (2005 Rev Ed). She emphasised that what was important was whether the invention has been disclosed sufficiently for a PSA to perform it (*Judgment* at [191]–[192]), and proceeded to consider the appellant's contentions on why Claim 1 was insufficient. One of these contentions was that Claim 1 of SG 872 was insufficient because the Metripol could not identify whether δ was within the SG 872 First Order (*Judgment* at [193]–[196]). She eventually rejected that contention because she accepted Dr Glazer's evidence that the PSA would know how to determine whether δ was within the SG 872 First Order using the Gap Theory (*Judgment* at [200]–[206]).

43 The Judge also found that Claim 62 had sufficiently disclosed the claimed invention. The appellant argued that the PSA would not know how to calibrate the other growth conditions to the chosen nitrogen concentration to grow an SG 872 Diamond.[73] The Judge rejected this submission given Dr Bergonzo's evidence that the missing details would be known to a PSA with a working knowledge of the research and development of CVD diamond synthesis (*Judgment* at [285]).

44 Another of the appellant's submissions was that the insufficiency of Claim 62 was demonstrated by how the single crystal CVD diamond material

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72 The version as at 30 April 2014.

73 DCS2 at para 428 (III(G6) ROA 10).

grown in Examples 1 and 14 of SG 872 as well as Examples 4 and 6 of SG 508 had different qualities, even though these examples disclosed a growth process where the synthesis atmosphere had 300ppb to 5ppm nitrogen. The Judge rejected this submission, noting that the respondent had explained that the difference in other parameters of the growth process (such as gas flow and methane concentration in the synthesis atmosphere) between SG 508 and SG 872 resulted in a diamond with different qualities being grown. She also observed that these other parameters did not, in any event, constitute the inventive concept of SG 872 (*Judgment* at [286]–[287]).

45 Given her finding that Claims 1 and 62 of SG 872 were valid, the Judge did not revoke SG 872 and proceeded to find that both Claims 1 and 62 had been infringed (*Judgment* at [416]). In particular, she found that the Samples infringed Claim 1 on the basis that they fulfilled limbs ii) and iii) of Claim 1 (*Judgment* at [431]–[443]). The Judge therefore made the following orders, amongst others (*Judgment* at [478(a)]–[478(c)]):

(a) a declaration that SG 872 is valid and has been infringed;

(b) an injunction to restrain the defendant, whether by themselves, their directors, officers, servants, agents from (a) making, disposing of, offering to dispose of, using, importing and/or keeping products which infringe SG 872, and/or (b) using or offering for use in Singapore processes which infringe SG 872; and

(c) an order for the delivery up and/or destruction, to be verified upon oath, of all products or articles which infringe SG 872.

The parties' cases

Appellant's case

46 The appellant's attack on the Judge's decision cuts across many areas of patent law, such as novelty, inventive step, and sufficiency. Much reliance has also been placed on concepts recognised in English law which have not been recognised locally, such as "*Biogen* insufficiency". For the purposes of the present appeal, we only need to focus on two parts of the appellant's case, both of which concern the non-fulfilment of the sufficiency requirement and are determinative of this appeal.

47 The first relates to the insufficiency of Claim 62 on the basis that the patent specification fails to teach the "novel" growth process clearly and completely enough for it to be performed by a PSA. In particular, the appellant faults Claim 62 for not disclosing "what ranges of temperature, gas flow rate or methane concentration will give diamond material within claim 1iii) or any other product claims for that matter."[74] We shall refer to these variables, and any other variables in the patented CVD growth process (other than the concentration of nitrogen), as the "Other Growth Conditions". The appellant argues that it is not enough to point to the examples in SG 872 because these "do not support a claim of the breadth of claim 62."[75] As a result, the PSA is "left with a long and extensive research project to find out what ranges of these *other* process parameters are required to obtain claim 1iii) or 1ii) diamond material" and that, therefore, *SG 872*, is insufficient.[76]

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74 Appellant's Reply ("AR") at paras 44 and 52.

75 AR at paras 46 and 50.

76 AR at para 52; Appellant's Counsel's Note ("ACN") at para 11(e).

48 The appellant contends that the respondent's *own arguments* under novelty establish insufficiency. Relevantly, the respondent argues that Examples 4 and 6 of SG 508, which teach the use of 2.5ppm and 3.8ppm of nitrogen in the synthesis gas mixture respectively, do not anticipate SG 872 because there are "a lot of differences" in terms of gas flow, temperature and methane concentration between those examples and Claim 62.[77] The respondent asserts on this basis that Examples 4 and 6 in SG 508 do not anticipate Claim 62 because following those examples will not inevitably lead to the production of an SG 872 Diamond.[78] But if this is correct, the appellant points out that it must mean "there are other ranges of essential parameters for the process in SG 872 to 'work'" and that their omission from Claim 62 or the specification of SG 872 means that the invention is insufficiently disclosed.[79]

49 Before proceeding further, we note the respondent's submission that pursuant to O 57 r 9A(5B) of the Rules of Court (2014 Rev Ed), the appellant cannot impugn the clarity and completeness of SG 872 as this ground of insufficiency is not particularised in the Appellant's Case (the "O 57 Objection").[80] Notwithstanding the respondent's contentions, we are inclined to consider the appellant's arguments on this issue (see *Oxley Consortium Pte Ltd v Geetex Enterprises Singapore (Ptd) Ltd and another matter* [2021] 2 SLR 782 at [45]; *Global Yellow Pages Ltd v Promedia Directories Pte Ltd and another matter* [2017] 2 SLR 185 at [22]). Although the Appellant's Case focused on another type of insufficiency that we will turn to next, it foreshadowed the possibility of other insufficiency arguments arising "depending on how the

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77 RC at paras 95–97.

78 RC at para 98.

79 AR at para 46.

80 Respondent's skeletal arguments ("RSA") at para 38.

Respondent trie[d] to avoid invalidity."[81] And in its Reply, the appellant developed its submissions on this point in direct response to the Respondent's Case. The respondent also did not press the O 57 Objection in oral submissions and instead dealt substantively with the appellant's arguments in question.[82] There is therefore no procedural impropriety afoot and/or prejudice to the respondent that precludes the appellant from relying on this ground of insufficiency.

50 The second part of the appellant's case which we will focus on concerns the insufficiency of Claim 1 arising from ambiguity or uncertainty. The appellant argues that the Judge erred in failing to consider this type of insufficiency, which arises where the PSA does not know whether he is inside or outside the claim.[83] On the facts, it argues that the Claim 1 and SG 872 are insufficient because the PSA cannot tell whether the δ value of a particular single crystal CVD diamond was within the SG 872 First Order and hence within the scope of the asserted monopoly.

Respondent's case

51 The respondent supports the Judge's findings that SG 872 is *not* anticipated, obvious or insufficiently disclosed.

52 Its case is that SG 872 claims a new single crystal CVD diamond material with exceptionally low strain and a new method of producing said diamond material.[84] By way of a letter dated 21 September 2022, which was

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81 AC at para 148.

82 See, *eg*, Transcript, 24 January 2022, p 50:9–19.

83 AC at para 150.

84 RSA at paras 1–4.

sent in response to our query (see above at [10]), the respondent accepts that each *product* claim in SG 872 covers a *class* of products. The distinction between a single product and a class of products is relevant to the issue of insufficiency. If the claim is to a single product, then it is sufficient if it enables the making of that one product. If, on the other hand, the claim is to a class of products, that class of products is sufficiently enabled only if the skilled man can work the invention in respect of all members of the class (*Regeneron Pharmaceuticals Inc v Kymab Ltd and another* [2016] EWHC 87 (Pat) at [209]). We return to these principles at [108]–[112] and [184] below.

53 In response to the appellant's submission that the patent is insufficient because it fails to teach the Claim 62 growth process clearly and completely enough, the respondent argues that the correct test is whether the patent's specification *as a whole* discloses the invention sufficiently.[85] It argues that the specification of SG 872 (in particular Example 1 read with Example 9) gives full disclosure of the Other Growth Conditions, including temperature, pressure and gas flow rates. It stresses that the burden is on the appellant to show that the invention is unworkable by the PSA who is "trying to give practical meaning to the patent specification."[86]

54 Next, as to the appellant's submission that the Judge erred in failing to consider a further type of insufficiency brought about by ambiguity or uncertainty, the respondent submits that the Judge rejected the appellant's argument on insufficiency arising from "ambiguity", on the basis that in *First Currency Choice* we held that lack of clarity under s 25(5)(*b*) of the Patents Act

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85 Respondent's Counsel's Note ("RCN") at para 51(b).

86 RCN at para 51(d).

(2005 Rev Ed) is not a ground for revocation.[87] It further submits that the appellant has not explained how the Judge erred in following *First Currency Choice*, or why the court should depart from the position at law that lack of clarity is not a basis for revocation.[88] On the facts, the respondent submits that the PSA can determine that δ is within the SG 872 First Order by using four different methods.[89]

Issues to be determined

55 In light of the foregoing, the issues we shall address in this decision are as follows:

(a) Whether the product claims in SG 872 cover a single product or a range of products?

(b) Whether any or all of the claims in SG 872 are invalid due to insufficiency?

(c) Whether SG 872 should be revoked in its entirety?

Foundational principles

Patents in general

56 To set the context for the analysis that follows, we first touch on some foundational principles that guide us, beginning with the objectives of the patent regime and how these are advanced. Where relevant, we also explain principles of patent law which are engaged in the reasoning of this judgment, or which provide context to our analysis.

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87 RC at para 173.

88 RC at para 174.

89 RC at para 175.

57 The patent regime has two main aims. First, it seeks to encourage innovation by granting the patentee a monopoly over the patented invention for a limited period (meaning the right to exclude others from using that invention). In this regard, each patent demarcates the monopoly which the patentee asserts. Apart from incentivising innovation with the promise of a monopoly right, the patent regime also seeks to disseminate knowledge. This second objective, the dissemination of knowledge, is as important as the first and is achieved by requiring the patentee to teach, in the patent specification, how to work or make the asserted invention. This is so that the public, following the expiry of the limited-term monopoly, may freely use or build on the invention in light of the teachings in the patent (see Ng-Loy Wee Loon, *Law of Intellectual Property of Singapore* (Sweet & Maxwell, Revised 3rd Ed, 2022) ("*Ng-Loy*") at paras 29.1.2–29.1.3 and Colin Birss *et al*, *Terrell on the Law of Patents* (Sweet & Maxwell, 19th Ed, 2022) ("*Terrell*") at para 1-01).

58 To ensure that patents effectively incentivise innovation in furtherance of the first aim, the patent regime only grants monopolies over deserving inventions. An invention must be novel, contain an inventive step and be capable of industrial application, before it will be patentable (ss 13–16 of the Patents Act (2005 Rev Ed)). If any one of these requirements is not met, the patent may be revoked (s 80(1)(*a*) of the Patents Act (2005 Rev Ed)). We briefly introduce the concepts of novelty and inventive step as the parties have made submissions on them (although, as foreshadowed at [46] above, we will not analyse the parties' submissions on these requirements in this judgment).

59 Novelty requires the invention to be new, in that it does *not* form part of the state of the art (s 14(1) of the Patents Act (2005 Rev Ed)). If directions forming part of the state of the art (meaning a piece of prior art) lead inevitably to something that would infringe the patent, the invention lacks novelty and the

patent can be revoked (*Mühlbauer AG v Manufacturing Integration Technology Ltd* [2010] 2 SLR 724 ("*Mühlbauer*") at [17]). The state of the art comprises *all* matter (whether a product, a process, information about either, or anything else) which has at any time before the priority date of that invention been made available to the public (whether in Singapore or elsewhere) by written or oral description, by use or in any other way (s 14(2) of the Patents Act (2005 Rev Ed)). By default, the "priority date" of an invention is the filing date of the patent application (s 17(1) of the Patents Act (2005 Rev Ed)). Under certain conditions, a patentee can depart from this default position by claiming that the priority date of the invention takes reference from the date of filing of an earlier patent application or applications (see s 17(2) of the Patents Act (2005 Rev Ed)), which has the effect of limiting the state of the art to what it was at that earlier date. On the other hand, a later priority date may widen the pool of material which may anticipate the invention.

60 An invention shall be taken to involve an inventive step if it is not obvious to a PSA, having regard to any matter which forms part of the state of the art as at the priority date of the invention (s 15 of the Patents Act (2005 Rev Ed)). When considering the issue of obviousness, it is assumed that the invention is novel and differs in some identifiable respect from the prior art. The key question then is whether these differences constitute steps that would have been obvious (*Ng-Loy* at para 30.2.48; *Mühlbauer* at [20] citing *Windsurfing International Inc v Tabur Marine (Great Britain) Ltd* [1985] RPC 59 ("*Windsurfing*")). This is a question of degree.

61 Separately, the second aim of the patent regime, namely knowledge dissemination, is advanced by the "sufficiency" or "enabling disclosure" requirement, which provides that the patent specification must disclose the invention in a clear and complete manner for it to be performed by a PSA. This

requirement is statutorily embodied in ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed), with the latter providing for the revocation of the patent if the patent specification is insufficient.

62 Underlying the novelty, obviousness and sufficiency inquiries is the need for the court to first construe the patent claims before undertaking the substantive analyses (*Ng-Loy* at paras 30.2.34 and 30.2.52; *Terrell* at para 13-15). Claim construction identifies the invention that is said to be novel, non-obvious and sufficiently disclosed, and in respect of which the monopoly is claimed. It is therefore a pivotal exercise that frames the substantive analyses which follow thereafter.

63 Another point of commonality is that the court, when undertaking the novelty, obviousness and sufficiency inquiries, as well as in construing the claims, dons the mantle of the PSA, that is, someone in the field of technology relevant to the invention in question and who possesses, amongst other characteristics, common general knowledge in the art (*Mühlbauer* at [18] (novelty); *ASM Technology Singapore Pte Ltd v Towa Corp* [2018] 1 SLR 211 at [78] (obviousness); *First Currency Choice* at [60]–[61] (sufficiency); *Lee Tat Cheng v Maka GPS Technologies Pte Ltd* [2018] 1 SLR 856 ("*Lee Tat Cheng (CA)*") at [41] (claim construction)). Common general knowledge is information which, at the relevant date, is common knowledge in the art to which the alleged invention relates, so as to be known to duly qualified persons engaged in that art (*British Thomson-Houston Co Ltd v Stonebridge Electrical Co Ltd* (1916) 33 RPC 166 at 171; *Terrell* at para 8-61).

64 Whilst the PSA and his common general knowledge are important concepts which feature in multiple areas of patent law, they assume relevance in different ways. When determining whether the patented invention is novel or

contains an inventive step, the PSA employs his common general knowledge to interpret prior art, amongst other purposes (see *Mühlbauer AG* at [20], citing *Windsurfing*; *Synthon BV v SmithKline Beecham plc* [2005] UKHL 59 at [32]; *Terrell* at paras 8-62, 11-55, 12-10 and 12-19). Interpreting the prior art is crucial to determining what information is conveyed to the PSA at the priority date of the patent in suit or the date on which the piece of prior art (such as a book or journal) was published and whether that information renders the invention obvious and/or anticipates the invention (see *Terrell* at paras 11-55–11-60 and 12-10). However, this is not the case where claim construction and sufficiency are concerned. In these contexts, the PSA mainly directs his common general knowledge towards interpreting the patent claims and working the invention disclosed therein (see *Lee Tat Cheng v Maka GPS Technologies Pte Ltd* [2018] 3 SLR 1334 ("*Lee Tat Cheng (HC)*") at [54]; *Genelabs Diagnostics Pte Ltd v Institut Pasteur and another* [2000] 3 SLR(R) 530 ("*Genelabs (CA)*") at [61]–[63]).

65 Further, the precise assumptions applicable to the PSA are not identical in all areas of patent law. For instance, in matters of claim construction and sufficiency, the PSA is assumed to have the patent specification in his hands whereas when considering the issue of obviousness, the PSA is deemed *only* to be considering the prior art without the patentee's invention in front of him (*Terrell* at para 8-19).

66 The central issues concerned in our decision relate to claim construction and insufficiency. To reiterate, the former identifies the invention that is the subject of the claims, whilst the latter entails a consideration of whether the patent specification sufficiently enables a PSA to perform that invention. It is in this context that we now turn to examine the characteristics of the PSA relevant

to our reasoning in the present judgment, and the common general knowledge he (or, the notional team comprising the PSA) would possess.

The person skilled in the art

67 The PSA, apart from possessing common general knowledge in the art, also has a practical interest in the subject matter of the patent and is likely to act on the directions given in it with the desire to make the directions in the patent work. He is a reasonably intelligent but unimaginative workman or technician who has the skill to make routine workshop developments, but not to exercise inventive ingenuity or think laterally (*Ng Kok Cheng v Chua Say Tiong* [2001] 2 SLR(R) 326 ("*Ng Kok Cheng*") at [21]; *First Currency Choice* at [28]; *Ng-Loy* at para 30.1.12).

68 The PSA may be an individual person or a notional team of people. The need for a notional team may arise where it is clear that the patent specification engages more than one set of skills which in the real world would be possessed by more than one person. This may be the case where the art is one that concerns a highly developed technology. In such circumstances, the specification can be said to be addressed to a team, with each member contributing his or her individual skill which would in turn be employed in combination in interpreting and carrying into effect the instructions in the patent (*Terrell* at paras 8-35–8-36; *The General Tire & Rubber Company v The Firestone Tyre and Rubber Company Limited and others* [1972] RPC 457 ("*General Tire*") at 483; *Schlumberger Holdings Ltd v Electromagnetic Geoservices AS* [2010] EWCA Civ 819 at [33]; *Halliburton Energy Services, Inc v Smith International (North Sea) Ltd* [2006] RPC 2 at 46; see also *Institut Pasteur and another v Genelabs Diagnostics Pte Ltd and another* [2000] SGHC 53 ("*Genelabs (HC)*") at [194]). For the avoidance of doubt, the formation of such a notional team does not mean

that the common general knowledge of the PSA is only that which is common to persons with these different backgrounds (*Inhale Therapeutic Systems Inc v Quadrant Healthcare Plc* [2001] All ER (D) 211 (Jun) at [39]–[42]; *First Currency Choice* at [31]).

69 As noted at [65] above, when considering the issues of claim construction and sufficiency, the PSA is assumed to have the patent specification in his hands and have the same attributes for both inquiries (see *Terrell* at para 8-19). The PSA, for the purposes of the insufficiency inquiry, is "trying to carry out the invention and achieve success" (*Zipher Ltd v Markem Systems Ltd and another* [2008] EWHC 1379 (Pat) ("*Zipher*") at [366]). It is through the eyes of the PSA that the patent will fall to be interpreted, and the PSA must know how to perform the invention upon reading the specification in light of his common general knowledge.

70 Moving now to the PSA in the present case, the Judge found that the PSA, for the purpose of claim construction, would be a notional team of persons working in the field of growing CVD diamonds, with expertise in diamonds (including natural, HPHT and CVD diamonds) and the sciences (including applied physics, optical engineering and material sciences) (*Judgment* at [14]):

> In the present case the defendant's PSA is a composite person having a Master's degree in mechanical or chemical engineering and having a doctorate in applied physics, electrical engineering, optical engineering or a closely related field, aided by an engineer/technician with skills in mechanical polishing, laser cutting and correlated measurements. The plaintiff disputes this, and contends that the PSA is a team of people collectively having a Bachelor of Science in physics, chemistry or material sciences, and knowledge of diamond properties in all its forms at the material time (natural, high-pressure high-temperature ('HPHT') and CVD diamonds) as well as working knowledge of CVD diamond synthesis and commercial production. *This disagreement has no practical significance, as no finding in the case turns upon this fine distinction. The present case would require consideration of a team of persons working*

> *in the field of growing CVD diamonds. In my judgment, the relevant PSA in such a field would include a team of individuals with expertise in diamonds and science generally, with access to individuals possessing doctorate qualifications.*
>
> [emphasis added]

71 The parties have not challenged the Judge's finding in that passage of the composition and qualifications of the notional team of persons. Further, as already mentioned at [69] above, the PSA for the purposes of claim construction and sufficiency will be the same. However, before us, the appellant seeks to impute the PSA with the specific purpose of growing single crystal CVD diamond material for use in the most demanding optical applications – "etalons and anvils".[90] The respondent rejects this imputation.[91] Although this dispute between the parties mainly arises in the course of their submissions on novelty and obviousness, a proper identification of the PSA's practical interest is also important in the context of claim construction and sufficiency.

72 As earlier stated, the PSA is trying to carry out the invention (see [69] above) and has a practical interest in the "subject matter of the patent" (see [67] above). What the subject matter of the patent is should be determined by reference to the patent specification. Having regard to the specification of SG 872, we are satisfied that the PSA's interest would not be limited to producing etalons and anvils. The patent specification describes the invention in SG 872 in more general terms – a single crystal CVD diamond material which possesses certain desirable characteristics, and which can be used in connection with a *wide range* of optical applications which "*include but are not limited to*" optical windows, laser windows, optical reflectors, optical refractors and lenses,

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90 Appellant's Skeletal Arguments ("ASA") at para 21; AR at para 12; Transcript, 20 January 2022, p 15:24–26.

91 RC at paras 44, 68, 148 and 165.

diffractive optical elements, etalons, ornamental use and anvils [emphasis added].[92] Accordingly, the PSA's practical interest lies in using the growth process taught in SG 872 to grow low-strain diamonds for a *range* of optical applications.

The common general knowledge

73 As already noted, the PSA is imputed with common general knowledge in the art. He draws upon such knowledge to understand a patent and in his attempts to carry it into effect. As mentioned at [63] above, common general knowledge is information which, at the relevant date, is common knowledge in the art to which the alleged invention relates, so as to be known to duly qualified persons engaged in that art. The relevant art to which the alleged invention is to be gathered from the patent specification itself (*First Currency Choice* at [30]).

74 Common general knowledge is ordinarily established, where not agreed, by expert evidence which is usually supported by reference to textbooks or other reference works which the PSA would be expected to have access to and acquire his information from. The publication at or before the relevant date of such documents may be *prima facie* evidence tending to show that the statements contained in them were part of the common general knowledge, but that is far from complete proof as those statements may well have been discredited, forgotten or ignored (*Terrell* at paras 8-75–8-77). It is also not sufficient just to point out that it was said in a scientific paper that has been well circulated. A particular disclosure does not become common general knowledge merely because it is widely read, and still less because it is widely circulated. To prove that a particular disclosure in scientific paper has become common general

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92 BOM at p 322.

knowledge, it must be shown that it is generally known and generally *regarded as a good basis for further action* by the bulk of those who are engaged in the particular art to which the disclosure relates (*General Tire* at 480–481).

75 In the present case, as identified by the Judge, the art relates to the growth of CVD diamonds (*Judgment* at [14]). In our view, this includes methods of measuring the physical properties of the CVD diamonds grown. Based on the Primer,[93] the parties are agreed that the information set out at [11]–[27], [32]–[35] and [38] above constituted common general knowledge in the art of growing CVD diamonds at the relevant time. There are further points of agreement on what was part of the common general knowledge and they will be mentioned, where relevant, when we apply the principles of sufficiency to the facts of this case. But before going into the issue of sufficiency, it is pertinent for us to first consider how the claims, in particular the *product* claims, ought to be construed. It is to this issue that we now turn.

Patent construction: do the product claims in SG 872 cover a single product or a class of products?

76 The question here is whether the product claims in SG 872 cover a single product or a *class* of products. As we shall see, this affects what, in *law*, must be enabled by the specification of SG 872 (see [108]–[112] below), and whether the claims in SG 872 are in fact insufficient (see, *eg*, [184]–[185] below).

77 Whether the patent claims a single product or a range of products is a question of construction of the claim(s) in the patent (*Regeneron Pharmaceuticals Inc v Kymab Ltd* [2021] 1 All ER 475 ("*Regeneron (SC)*") at [3]. Before setting out the principles on claim construction in detail, we touch

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93 See Primer at p 1 *et seq*.

on the relevance of the priority date(s) of the product claims in SG 872 to their interpretation.

78 In *Lee Tat Cheng (CA)* at [53] and [55], we held that the relevant date for claim construction is *the date of the patent application* (meaning its filing date) (see also *Lee Tat Cheng (HC)* at [49]). However, it does not appear that the patentee there claimed that its invention took priority from an earlier filing. If the patentee there had claimed priority, a conundrum noted by the authors of *Terrell* would have arisen. That conundrum arises from the fact that the English cases are divided over whether the relevant date for patent construction is the priority date or filing date of the patent application, or the publication date of the patent (see *Terrell* at paras 9-08–9-014). At present, the respondent *does* claim priority from GB Patent Application No 0227261.5 ("GB 261"), which was filed on 21 November 2002. The parties agree that Claim 1ii) takes priority from 21 November 2002 but disagree on whether Claims 1iii) and 62 enjoy the same priority.[94] This specific complication did not present in *Lee Tat Cheng (CA)*. However, nothing in this case turns on which of the three dates should be adopted in law and the parties do not submit otherwise. We therefore prefer to leave this issue for an appropriate case and proceed on the basis that the relevant date for patent construction is the filing date of SG 872 (that is, 20 November 2003). Consequently, any common general knowledge which may be relevant to patent construction must be shown to exist by this date. In addition, whether the asserted priority date is granted only assumes significance in this case in relation to the issues of novelty and obviousness. However, as stated at [46], we need not reach or address the latter issues in this judgment.

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[94] AC at paras 26 (Claim 1iii)) and 31 (Claim 62).

79 Turning to the substantive principles on claim construction, in *Lee Tat Cheng (CA)*, we reaffirmed the correctness of construing a patent's claims purposively (at [41] and [55]). This entails, among other things, viewing the claims through the lens of the PSA (at [41]):

> (a) In ascertaining the true construction of a patent specification, the claims themselves are the principal determinant. What is not claimed is deemed to be disclaimed.
>
> (b) The description and other parts of the patent specification form the context for, and may assist in, the construction of the claims.
>
> (c) The claims are to be construed purposively, and not literally. This would give the patentee the full extent, but no more than the full extent, of the monopoly which a person skilled in the art, reading the claims in context, would think the patentee was intending to claim. In this regard, the starting point is to ask the threshold question: What would the notional skilled person have understood the patentee to mean by the use of the language of the claims? The *Improver* questions (see [30] above), which were derived from *Catnic* ([26] supra), have also been used as guidance in construing patent claims.
>
> (d) As a general rule, the notional skilled person should be taken to be a workman or technician who is aware of everything encompassed in the state of the art and who has the skill to make routine workshop developments, but not to exercise inventive ingenuity or think laterally.
>
> (e) Purposive construction does not entitle the court to disregard clear and unambiguous words in a patent claim, and the court is not entitled to rewrite or amend the claim under the guise of construction. In construing a claim purposively, the language that the patentee has adopted is more often than not of utmost importance. It is not permissible to put a gloss on or expand a claim by relying on a statement in the patent specification.
>
> (f) If an allegedly infringing article falls within the words of one of the claims of a patent properly construed, the patent would have been infringed. To constitute infringement, the article

> concerned must usurp each and every one of the essential elements of the claim in question.

80 The patent "specification", referred to in the passage above, comprises the description of the invention, drawings (if any) and the claims (*Halsbury's Laws of Singapore* vol 13(3) (LexisNexis, 2020 reissue) ("*Halsbury's Singapore IP*") at para 160.321). Examples illustrating how to carry out the invention also form part of the patent's specification (see rr 19(3) and 19(5)(*e*) of the Patents Rules (1996 Rev Ed)). However, the claims serve a different purpose from the rest of the patent's specification, as explained by Floyd LJ in *Adaptive Spectrum & Signal Alignment Inc v British Telecommunications PLC* [2014] EWCA Civ 1462 at [45]:

> ... The specification describes and illustrates the invention, the claims set out the limits of the monopoly which the patentee claims. As with the interpretation of any document, it is conceivable that a certain, limited, meaning may be implicit in the language of a claim, if that is the meaning that it would convey to a skilled person, even if that meaning is not spelled out expressly in the language. However it is not appropriate to read limitations into the claim *solely* on the ground that examples in the body of the specification have this or that feature. The reason is that the patentee may have deliberately chosen to claim more broadly than the specific examples, as he is fully entitled to do.
>
> [emphasis in original]

81 The parties initially appear to have approached this appeal on the basis that each product claim is a claim to a single product – a new CVD diamond material. For instance, the Appellant's Case states that "Claim 1 is a product claim, so the eight alternates in Claim 1 disclose the same physical thing – a particular CVD diamond material, characterised in eight different ways".[95] The Respondent's Case states that "SG 872 claims *a* new diamond *material*"

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95 AC at para 19.

[emphasis in original omitted; emphasis added in italics].[96] Both parties took similar positions in their written closing submissions in the second tranche of the trial.[97]

82 We wrote to the parties on 14 September 2022 seeking clarification on this issue. The appellant confirmed its view that SG 872 teaches the PSA a new method to "grow *one* product, i.e. a CVD single crystal diamond material having one or more of the specified parameters." It argued that the "different ranges and combination of properties in each product claims [were] therefore variations of the *same* product grown from the one process described in SG 872" [emphasis added].[98] In contrast, the respondent took the view that each product claim could be said to cover a *class* of products. In particular, the respondent noted that "given that the product claims of SG 872 claim, *inter alia*, a range of values (or depend on a claim which does), these would cover a class of products meeting the values within that range as opposed to an individual product."[99]

83 We agree with the respondent. Properly construed, each claim asserts a monopoly over a *class* of single crystal CVD diamond materials.

84 We turn first to Claim 1, which, as noted above, is the claim that all the other product claims refer back to. In our judgment, Claim 1 can be infringed by various types of single crystal CVD diamond materials, each with a different combination of the physical properties defined in the limbs of Claim 1. That the diamond materials falling within Claim 1 may possess different combinations of physical properties is clear from the words in the *chapeau* of Claim 1: "A

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96 RC at para 11.

97 PCS2 at para 871 (III(G3) ROA 122–123); DCS2 at para 56 (III(G6) ROA 36).

98 Respondent's letter dated 21 September 2022 at para 5.

99 Appellant's letter dated 21 September 2022 at para 2(b).

CVD single crystal diamond material which shows *at least one of the following* characteristics" [emphasis added]. Our reading of the plain language of Claim 1 is fortified by the description of the invention in the specification of SG 872. The relevant portion of the description reads as follows:[100]

> The diamond material of the invention can be tailored to specific applications, and although it ***may not be endowed with all of the above properties*** in all cases, in many applications it is the ability of the diamond material to show a ***substantial set or particular combination*** of the above properties which makes its use particularly beneficial. For example, for use as an etalon, the material may require optical homogeneity, low absorption, high thermal conductivity and the ability to be processed flat and parallel, but laser damage thresholds and mechanical strength may be less important.
>
> [emphasis added in bold italics]

The "above properties" referred to in the passage include optical homogeneity, effective refractive index, birefringence, optical absorption, optical scatter, laser damage threshold, thermal conductivity, parallelism, flatness and mechanical design strength.[101] Thus, the description indicates that the invention covers a range of single crystal CVD diamonds possessing different combinations of physical properties.

85 Further, as noted in *Lee Tat Cheng (CA)* at [41(c)], the language of the claim must be construed through the eyes of a PSA. In this regard, we found the evidence of Dr Mark Edward Newton ("Dr Newton"), the respondent's expert witness, to be instructive. As the respondent alluded to in its letter of 21 September 2022,[102] Dr Newton testified that the various limbs in Claim 1 cover optical properties which "may be related but remain ***different***" [emphasis added

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100 BOM at p 309.

101 BOM at pp 301–308.

102 Respondent's letter dated 21 September 2022 at para 2(a).

in bold italics].[103] He added that "[m]any are not directly derivable one from another".[104] It is not clear if these observations also apply to Claims 1ii) and 1iii), which both relate to birefringence. Dr Newton's evidence nevertheless reinforces our understanding that diamonds which fulfil different combinations of limbs in Claim 1 are *in fact* different diamonds. Our conclusion would be different if the measurements in each limb of Claim 1 were different ways of quantifying the *same* property.

86 Although Dr Nebel's first report dated 13 May 2019 ("Dr Nebel's 1st Report") stated that a diamond satisfying one limb of Claim 1 will also satisfy all remaining limbs, and that the properties mentioned in Claim 1 are "merely ... different measurement techniques for a ***common aspect*** of the diamond" [emphasis added in bold italics], we reject this.[105] For one, he offered no credible evidence in his Reply Report dated 26 June 2019 or oral testimony to support this assertion. In his reply report, Dr Nebel asserted that measurements like "dislocation density, Raman peak width, X-ray rocking curve width and birefringence" measure "strain in diamond ... and any change in strain in a diamond reflects a proportional change in these measurement parameters."[106] But Dr Nebel did not explain nor has the appellant otherwise shown that the optical properties or measurements described in each limb of Claim 1, including optical homogeneity, free spectral range, contrast ratio, insertion loss and variation in refractive index, merely measure a common property or will necessarily be present if one limb of Claim 1 is fulfilled. Crucially, Dr Nebel's evidence does not square with the specification of SG 872. The "Summary of

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103 Newton-2 at paras 79, 83 (I RSCB 173).

104 Newton-2 at para 76 (1 RSCB 171).

105 Dr Nebel's 1st Report ("Nebel-1") at para 69 (III(B13) ROA 90).

106 III(B62) ROA 93 (para 223); see also III(D5) ROA 119:3–6.

the Invention" states clearly that the CVD single crystal diamond material invented "may not be endowed with all of the above properties in all cases", but should show "at least one, preferably at least two, more preferably at least three, and even more preferably at least four" characteristics which are listed. The listed characteristics in the Summary of the Invention correspond to properties defined under the limbs in Claim 1, and include optical homogeneity (see Claim 1i)), birefringence (see Claims 1ii) and 1iii)), effective refractive index (see Claim 1iv)), free spectral range ("FSR") (see Claim 1v)) and contrast ratio (see Claim 1vi)).[107] Moreover, in its submissions below, the appellant did not appear to dispute the correctness of the portion of Dr Newton's evidence that we have accepted at [85] above.[108]

87 Turning now to the subsequent product claims, these likewise cover a range of diamonds. These claims may be placed into three categories based on their phraseology, all of which incorporate Claim 1. The first category of claims incorporates all preceding claims, including Claim 1. An example is Claim 6, which states: "A CVD single crystal diamond material according to *any one of the preceding claims*, which has a value of effective refractive index of 2.3964 to within an accuracy of +/-0.001" [emphasis added].[109] The second category of claims expressly incorporates a preceding claim, the latter of which incorporates Claim 1. An example is Claim 7, which states: "A CVD single crystal diamond material according to claim 6, which has a value of effective refractive index of 2.39695 to within an accuracy of +/-0.0005." By referring back to Claim 6, Claim 7 likewise incorporates Claim 1. The third category consists only of

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107 See BOM at pp 301–308, 363–365.

108 See Defendant's skeletal oral reply at para 26 (III(G6) ROA 227), read with PCS2 at para 288 (III(G2) ROA 129–131).

109 BOM at p 309.

Claim 72. It reads: "A CVD single crystal diamond material produced by a method according to any one of claims 62 to 71." Claims 62 to 71 disclose a process that purportedly enables a PSA to produce a CVD diamond in one or more of Claims 1 to 61. By referencing all of these process claims, Claim 72 *includes* the range of diamonds defined under Claim 1.

88 Once a subsequent product claim incorporates Claim 1, it asserts a monopoly over a range of products. This is because any diamond within the *class* of products in Claim 1, which *also* fulfils the additional parameter expressed in the subsequent claim, will fall within that subsequent claim. It is irrelevant that the additional parameter in the subsequent claim is a *specific* or *single* value of a particular physical property (for instance, Claim 6, *in so far* as the additional parameter, "effective refractive index of 2.3964 within an accuracy of +/-0.001", expresses a single value of an effective refractive index) or a binary condition that is or is not satisfied (for instance, Claim 50, which has an additional requirement that the CVD diamond be formed into a polished gemstone). For reference, these claims state as follows:

> 6. A CVD single crystal diamond material according to any one of the preceding claims, which has a value of effective refractive index of 2.3964 to within an accuracy of +/-0.001.
>
> 50. A CVD single crystal diamond material according to claim 49, which is formed into a polished gemstone.

In these instances, the PSA would be satisfied that the patentee contemplated multiple diamonds in the Claim 1 range fulfilling the additional parameter in Claims 6 and 50. This is because the claim incorporates the *entire* range of diamonds in Claim 1 and there is nothing in the *language* of Claims 6 and 50, or for that matter in any other similar claim, to justify limiting the monopoly to a single product. We approach this on the basis that the respondent should be

afforded the full extent of the monopoly that is supported by the language it has adopted.

89 It is even more the case that where the additional parameter in the subsequent claim is itself expressed as a range of values, the claim covers a range of products. One example of this is Claim 4, which states: "A CVD single crystal diamond material according to any one of the preceding claims, wherein the modulus of the sine of the phase shift, |sin δ|, for at least 98% of the analysed area remains in first order and ***does not exceed 0.4***" [emphasis added in bold italics]. The phrase "does not exceed 0.4" indicates that Claim 4 monopolises a class of CVD single crystal diamond materials which have different |sin δ| values falling within the range of less than or equal to 0.4 (and which fulfil any preceding claim). By way of example, a CVD single crystal diamond material for which |sin δ| is equal to 0.2 as well as a CVD single crystal diamond material for which |sin δ| is equal to 0.3 could fall within the scope of Claim 4, subject to the diamond material also satisfying a preceding claim.

90 We find support for our construction of the product claims in the court's analysis in *Anan Kasei Co. Ltd and another company v Neo Chemicals and Oxides Ltd (formerly Molycorp Chemicals and Oxides (Europe) Ltd) and another company* [2019] EWCA Civ 1646 ("*Anan*"). The patent contained a product claim for ceric oxide, which stated as follows: "A ceric oxide consisting essentially of a ceric oxide, and wherein said ceric oxide has a specific surface area of not smaller than 30.0 m2/g when subjected to calcination at 900˚C for 5 hours." (at [8]). One issue which arose was whether a claim limited by reference to a desirable physical characteristic, namely high specific surface area, and specifying that it remained the same after being subjected to a high temperature, insufficiently described the invention and was invalid. In analysing this issue,

Floyd LJ (with whom Lewison and Peter Jackson LJJ agreed) noted that the claim covered a *class* of products (at [53]):

> The claim in the present case is to a *class of products* identified by their composition (consisting essentially of ceric oxide), their physical characteristics (their [specific surface area or] SSA), and their performance in the calcining test. That it is a class of products is plain from the fact that the claim *can be satisfied by a range of degrees of purity, and SSA, and from the fact that performance in the calcining test may vary from pass to distinction*.
>
> [emphasis added]

91 *Regeneron (SC)* is also illuminating. The patent in the suit contained a product claim which read as follows:

> A transgenic mouse that produces hybrid antibodies containing human variable regions and mouse constant regions, wherein said mouse comprises an *in situ* replacement of mouse VDJ regions with human VDJ regions at a murine chromosomal immunoglobulin heavy chain locus and an *in situ* replacement of mouse VJ regions with human VJ regions at a murine chromosomal immunoglobulin light chain locus.

Lord Briggs summarised the claim in these terms (at [15]):

> This is of course a product claim, seeking a monopoly for the 'making' (at first sight a strange but serviceable word to use of an animal) of a genetically engineered mouse having the characteristics described in the claim. The characteristics related both to what such a mouse does (namely produce the hybrid antibodies described) and to what is contained in its genome, namely the *Reverse Chimeric Locus, achieved by a process of 'in situ replacement' of the murine variable regions in both the light and heavy chain gene loci with the corresponding but of course different human variable regions*. The claim seeks protection for the making and exploitation of ***any type of mouse*** having those characteristics. Since the description of what the mouse does is more loosely worded than the description of what lies within its genome, it is the latter description which mainly controls the breadth of the claim.
>
> [emphasis added in italics and bold italics]

92 Relevantly, the appeal in *Regeneron (SC)* proceeded on the basis that the claim covered a *range* of transgenic mice, which differed based on the *amount* of human antibody genes implanted into the genome of the mouse (see [7], [16]–[17] and [81]). However, it bears highlighting that this issue of claim construction was resolved by the courts below and was *not* an issue in the appeal before the UK Supreme Court ("UKSC").

93 In the present case, by defining parameters using ranges of values or incorporating claims which do so, each product claim *in substance* claims or asserts a monopoly over a range of single crystal CVD diamonds, each with a different combination of physical properties.

94 Before leaving this issue, we note that while Dr Newton's evidence assisted us in construing the product claims, the expert evidence is not entirely clear as to whether each product claim covers a *class* of products or not. Be that as it may, claim construction is ultimately a task for the court. In particular, while expert evidence is useful in explaining the technical terms and technical features of the invention, the nature of the invention for which a patent is granted must be ascertained by the judge and not an expert (*Brooks v Steele and Currie* (1896) 13 RPC 46 at 73 and *Dyson Appliances Ltd v Hoover Ltd* [2002] RPC 22 at [13], cited in *Terrell* at paras 9-182 and 9-184). For the reasons given above, we hold that each of the product claims in SG 872 covers a range of products.

Insufficiency

The law of insufficiency

95 The sufficiency or enabling disclosure requirement finds statutory expression in ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed). Section

25(4) of the Patents Act (2005 Rev Ed), in the context of prescribing the requirements of a patent application, states that:

> The specification of an application shall disclose the invention in a manner which is clear and complete for the invention to be performed by a person skilled in the art.

96 Non-compliance with s 25(4) of the Patents Act (2005 Rev Ed) is a ground for revoking the patent, as provided for in s 80(1)(*c*) of the Patents Act (2005 Rev Ed):

> Subject to the provisions of this Act, the Registrar may, on the application of any person, by order revoke a patent for an invention on (but only on) any of the following grounds:
>
> …
>
> (*c*) the specification of the patent does not disclose the invention clearly and completely for it to be performed by a person skilled in the art;

97 It is this requirement that compels the inventor to tell the world how his invention works so that, after the expiry of the patent when his invention falls into the public domain, a PSA will have sufficient information to work the invention and build on it (see *Ng-Loy* at paras 29.1.3 and 30.3.1).

98 English case law may be instructive when interpreting the scope of the sufficiency requirement under our Patents Act (2005 Rev Ed). Section 25(4) of the Patents Act (2005 Rev Ed) is in materially similar terms as s 14(3) of the UK Patents Act 1977 (c 37) ("UK Patents Act 1977"), which reads:

> The specification of an application shall disclose the invention in a manner which is clear *enough* and complete *enough* for the invention to be performed by a person skilled in the art.
>
> [emphasis added in italics]

99 Section 80(1)(*c*) of the Patents Act (2005 Rev Ed) is also materially similar to s 72(1)(c) of the UK Patents Act 1977, which states:

> Subject to the following provisions of this Act, the court or the comptroller may by order revoke a patent for an invention on (but only on) any of the following grounds, that is to say—
>
> …
>
> (c) the specification of the patent does not disclose the invention clearly ***enough*** and completely *enough* for it to be performed by a person skilled in the art;
>
> [emphasis added in italics and bold italics]

100 Although the word "enough" is omitted in ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed) (and, for that matter, the same provisions in the Patents Act 1994 (2020 Rev Ed)), the sufficiency requirement in Singapore is *not* stricter. Our courts have held that a patent specification suffices if it is "clear enough" and "complete enough"; absolute clarity and completeness are not uncompromisingly required. This is because under ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed), as long as the specification is sufficiently clear "for [the invention] to be performed by a person skilled in the art", it does not matter that the specification does not state every single step required for performance. After all, the PSA does not have to be told what is self-evident or what is part of his common general knowledge (*First Currency Choice* at [73]; *Ng Kok Cheng* at [47] and [49]). In this regard, the local position is in line with the ss 14(3) and 72(1)(c) of the UK Patents Act 1977.

101 That said, not every aspect of English law on insufficiency is applicable in our context. The UK Patents Act 1977 was passed to give effect to the Convention on the Grant of European Patents, 5 October 1973, 1065 UNTS 199 ("European Patent Convention"). Section 130(7) of the UK Patents Act 1977 provides that certain provisions, including ss 14(3) and 72(1)(c) of the UK Patents Act 1977, were "so framed as to have, as nearly as practicable, the same effects in the United Kingdom as the corresponding provisions of the European Patent Convention". The English courts have thus approached the law in these

respects with the objective of striving for consistency between European and English patent law (*Regeneron (SC)* at [30]; *Generics (UK) Ltd and others v H Lundbeck A/S* [2009] 2 All ER 955 ("*Generics v Lundbeck (HL)*") at [86] *per* Lord Neuberger; *Merrell Dow Pharmaceuticals Inc and another v H N Norton & Co Ltd and another; Merrell Dow Pharmaceuticals Inc and another v Penn Pharmaceuticals Ltd and another* (1997) 33 BMLR 201 at 205). In interpreting and developing the jurisprudence under ss 14(3) and 72(1)(c) of the UK Patents Act 1977, the English courts have therefore introduced certain concepts into English law from European patent law to give effect to this harmonising objective. Such concepts, however, are not necessarily applicable to ss 80(1)(*c*) and 25(4) of the Patents Act (2005 Rev Ed), and their applicability falls to be determined with reference to the text and legislative objective of ss 80(1)(*c*) and 25(4) as well as the Patents Act (2005 Rev Ed) as a whole.

102 We begin by noting the policy that undergirds the sufficiency requirement. Both English and local case law have recognised that the sufficiency requirement lies at the heart of what is sometimes called the "patent bargain". As already alluded to above at [57], the inventor/patentee is rewarded with a limited-term monopoly over the claimed invention, in exchange for enabling a PSA to work the claimed invention and dedicating it to public use after the monopoly has expired (*Rohm and Haas Electronic Materials CMP Holdings, Inc (formerly known as Rodel Holdings, Inc) v NexPlanar Corp and another* [2018] 5 SLR 180 ("*Rohm*") at [161]; *Warner-Lambert Company LLC v Generics (UK) Ltd t/a Mylan and another* [2019] 3 All ER 95 at [17]). The patent bargain breaks down if the patent does not sufficiently teach a PSA how to perform the invention, in which case it makes little sense to reward the inventor/patentee with a monopoly. It is for this reason that the failure to satisfy the sufficiency requirement is a ground for patent revocation.

103 We now turn to set out general principles applicable to the legal requirement of sufficiency in Singapore. References to English jurisprudence will be made where appropriate.

104 It is well-settled under Singapore law that the burden of proving insufficiency rests on the party challenging the validity of a registered patent (*Ng Kok Cheng* at [48]).

105 The assessment of whether the legal requirement of sufficiency is met proceeds in two steps. The first step involves identifying the invention and deciding what it claims to enable the PSA to do. The second steps asks whether the specification enables him to do it (*Kirin-Amgen Inc and others v Hoechst Marion Roussel Ltd and others*; *Hoechst Marion Roussel Ltd and others v Kirin-Amgen and others* [2005] RPC 169 ("*Kirin-Amgen*") at [103] *per* Lord Hoffmann, cited with approval in *First Currency Choice* at [61]). Indeed, the court can only ascertain whether the disclosure has been sufficient after ascertaining what needs to be disclosed (meaning the invention).

106 Both steps of the inquiry require the court to don the mantle of a PSA possessing common general knowledge of the art. The first step involves the construction of the patent claims from the perspective of the PSA. Claim construction principles as set above at [79]–[80] are applied (see *Towa Corp v ASM Technology Singapore Pte Ltd and another* [2017] 3 SLR 771 at [66] and *Main-Line Corporate Holdings Ltd v United Overseas Bank Ltd and another (First Currency Choice Pte Ltd, third party)* [2007] 1 SLR(R) 1021 at [72]). At the second step, the PSA uses his common general knowledge to supplement the information contained in the specification in order to perform the invention (see *Genelabs (CA)* at [61]–[63]). The sufficiency inquiry at the second stage is undertaken with reference to the date of filing of the patent application (*Biogen*

Inc v Medeva PLC [1997] RPC 1 ("*Biogen*") at 54 *per* Lord Hoffmann, followed in *Kirin-Amgen Inc v Transkaryotic Therapies Inc* [2003] RPC 3 at 70). This is sensible, since s 25(4) of the Patents Act (2005 Rev Ed) imposes the requirement of sufficiency at the time the patent application is made (see also *Genelabs (HC)* at [202]; *Susanna Leong* at para 16.266). As an aside, since we are regarding the relevant date for construing the patent claims (see at [78] above) and assessing insufficiency as the date of filing of SG 872, and we do not intend to discuss the issues of novelty and obviousness, we need not rule on the respondent's claim for priority from GB 261.

107 Where the invention is a process, enablement at the second step requires that process to be carried out by the PSA; where the invention is a product, enablement requires the PSA to be able to make that product (*Generics v Lundbeck (HL)* at [20]; Roughton, Johnson & Cook, *The Modern Law of Patents* (LexisNexis, 5th Ed, 2022) ("*The Modern Law of Patents*") at para 4.37).

108 Regardless of the nature of the invention, the patent specification must enable the invention to be performed by the PSA over the full breadth of the monopoly claimed, as we explain further below. Lord Hoffmann, who delivered the leading decision in the House of Lords in *Biogen*, observed that this is a long-established principle in English law (at 48) (see also *Idenix Pharmaceuticals, Inc v Gilead Sciences, Inc and others* [2014] EWHC 3916 (Pat) ("*Idenix (HC)*") at [468]; *Regeneron (SC)* at [3] and [80]). Later in *Kirin-Amgen* at [102], Lord Hoffmann expressly applied this principle to s 72(1)(c) of the UK Patents Act 1977, which embodies the concept of sufficiency in the context of patent revocation:

> … The law on this point is contained in s. 72(1)(c) of the [UK Patents Act 1977]. A patent may be revoked if the specification does not disclose the invention 'clearly enough and completely enough for it to be performed by a person skilled in the art'.

> That means that the disclosure must enable the invention to be performed to the full extent of the monopoly claimed: see *Biogen Inc v Medeva plc* [1997] RPC 1, 48.

This court in *First Currency Choice* at [61] cited *Kirin-Amgen* at [102] with approval when setting out the applicable principles in relation to s 80(1)(*c*) of the Patents Act (2005 Rev Ed).

109 To illustrate what it means for a specification to enable the invention to be performed to the full extent of the monopoly claimed, Lord Hoffmann gave the following illustrations in *Biogen* at 48:

> … If the invention discloses a principle capable of general application, the claims may be in correspondingly general terms. The patentee need not show that he has proved its application in every individual instance. On the other hand, *if the claims include a number of discrete methods or products, the patentee must enable the invention to be performed in respect of each of them.*
>
> [emphasis added in italics]

Subsequently, in *H Lundbeck A/S v Generics (UK) Ltd and others* [2008] RPC 437 at [34], Lord Hoffmann re-iterated that where a claim is to a class of products, the class of products is enabled only if the PSA can work the invention in respect of all members of the class. The specification can show that this is empirically demonstrated or disclose a principle which can reasonably be expected to apply across the class.

110 However, the patent need not set out every detail necessary for the performance of the invention across its entire scope. As mentioned at [100] above, the patentee can leave the PSA to employ his skill and common general knowledge to work out what needs to be done. But the PSA must not be expected or required to exercise inventive ingenuity or exert undue effort in order to perform the invention across its entire breadth.

111 The requirement of enablement across the full breadth of the claim can be understood with reference to the patent bargain. The inventor/patentee should only be entitled to the full extent of the monopoly claimed if he has fulfilled his end of the bargain by disclosing the full scope of the invention clearly and completely enough. Only if this is done can the second aim of the patent regime, knowledge dissemination, be achieved by way of allowing the public to benefit from the invention after it falls into the public domain. A patent system which allows the inventor/patentee to monopolise more than that which he has sufficiently enabled may unduly stifle research, contrary to its primary aim of encouraging innovation (see *Regeneron (SC)* at [23]; Lionel Bently *et al*, *Intellectual Property Law* (Oxford University Press, 6th Ed, 2022) at pp 607–608). Hence, even where a patent specification is clear and complete enough to teach a PSA how to perform *part* of the claimed invention, that does not justify a monopoly over the entire breadth of the invention and the patent may be revoked pursuant to s 80(1)(*c*) of the Patents Act (2005 Rev Ed).

112 Before leaving this point, we note in passing that the majority of the UKSC in *Regeneron (SC)* held that it is enough if the patent enables the PSA to make "*substantially* all the types or embodiments of products within the scope of the claim" (at [56(iv)]) [emphasis added]. This threshold appears to be satisfied where there remain a "tiny or inconsequential number of embodiments which are not enabled" such that the scope of non-enablement is *de minimis* (at [36] and [56(v)]). The standard of substantiality was endorsed by the majority because it was the position in EU law (at [31]–[32] and [36]), and s 130(7) of the UK Patents Act 1977 requires interpretative consistency between European and UK patent law. We are not bound by a similar obligation. Without the benefit of submissions, we shall defer consideration of this aspect of *Regeneron (SC)* to an appropriate case. In any event, as we shall see, the threshold of substantiality does not have a material bearing on this case.

113 Next, although insufficiency is a single ground of objection to the validity of a patent contained in s 80(1)(*c*) of the Patents Act (2005 Rev Ed), there are distinct ways in which a patent may be insufficient (see *Zipher* at [362]; *Anan* at [22]). As will become clear, the appellant's case engages different aspects of the rule on patent sufficiency, two of which are determinative of this appeal. We now turn to consider the different ways a patent may be insufficient under English and/or Singapore law.

114 The first way in which a patent may be insufficient is where the patent specification is not clear and complete enough to enable the PSA to perform the invention across the whole breadth of the claim(s) without an undue burden (see *Terrell* at para 13-31). This objection, termed "classical insufficiency", is well-established in English and local jurisprudence (see *First Currency Choice* at [60]–[62]). In evaluating the merits of this allegation, the court has to assess the steps which would be necessary for the PSA to take under the patent's specification to carry out the invention (see *Zipher* at [363]).

115 Under English law, a patent specification which enables a PSA to perform the full breadth of the claim without undue effort (meaning that it is not classically insufficient), may nonetheless suffer from another type of insufficiency, known as "*Biogen* insufficiency". This form of insufficiency arises where the scope of the claim exceeds the technical contribution to the art made by the invention (see *Terrell* at para 13-09), whereas classical insufficiency is concerned with the mismatch between the scope of the claim and the method of performance taught in the patent specification. The "technical contribution to the art" does not refer to the technicalities of performing the claimed invention, but, more generally, to how the invention has in a practical sense added to or advanced the state of the art (that said, we note that the precise concept of "technical contribution to the art" has been articulated in various

ways (see *Generics v Lundbeck (HL)* at [95] *per* Lord Neuberger, at [45] *per* Lord Mance and at [30] *per* Lord Walker)).

116 Consider, for example, a claim to "a heavier than air flying machine" in a patent which only discloses how to make an airplane. Assume for the moment that an airplane is a new and non-obvious invention, and the patent specification is clear and complete enough for a PSA to make an airplane. The airplane is a machine that is (a) capable of flight and (b) heavier than air, and by teaching the PSA how to make an airplane, the patent specification has enabled performance of every integer (or "element", see *Rohm* at [103] and [179]) of the claim. In other words, the patent specification has sufficiently enabled the full breadth of the claim and can avoid a classical insufficiency attack. Yet, because the language of the claim has defined the invention in such general terms, the monopoly asserted by the claim is capable of extending to all other forms of heavier than air flying machines that are not airplanes and which may be manufactured by a wholly different process. The breadth of the claim thus exceeds what the patentee has contributed to the state of the art, in this example, how to make an airplane. This gives rise to *Biogen* insufficiency (see *Anan* at [52], citing *Biogen* at 52).

117 At present, Singapore patent law has not recognised the concept of *Biogen* insufficiency under s 80(1)(*c*) of the Patents Act (2005 Rev Ed), and it is unclear whether it should. We observe that *Biogen* insufficiency was first recognised by Lord Hoffmann in *Biogen* at 54, in the light of the jurisprudence under the European Patent Convention:

> In my view, however, there is an important difference between the 1949 and 1977 Acts which make decisions on the earlier Acts an unsafe guide. *Section 72(1)(c) of the [UK Patents Act 1977] is not only intended to ensure that the public can work the invention after expiration of the monopoly. It is also intended to give the court in revocation proceedings a jurisdiction which*

> *mirrors that of the Patent Office under section 14(3) o[f] the E.P.O. under article 83 of the EPC, namely, to hold a patent invalid on the substantive ground that, as the E.P.O. said in Exxon/Fuel Oils (T 409/91) [1994] O.J. E.P.O. 653, paragraph 3.3., the extent of the monopoly claimed exceeds the technical contribution to the art made by the invention as described in the specification.* In the 1949 Act, this function was performed by another ground for revocation, namely that the claim was not 'fairly based on the matter disclosed in the specification' (section 32(1)(i)). The requirement of sufficiency was therefore regarded as serving a narrower purpose. But the disappearance of 'lack of fair basis' as an express ground for revocation does not in my view mean that general principle which it expressed has been abandoned. The jurisprudence of the E.P.O. shows that it is still in full vigour and embodied in articles 83 and 84 of the EPC, of which the equivalents in the [UK Patents Act 1977] are section 14(3) and (5) and section 72(1)(c).
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> [emphasis added]

As the present appeal can be resolved without considering the applicability of *Biogen* insufficiency in Singapore, we leave this question open for determination in a future case.

118 Apart from classical insufficiency and "*Biogen* insufficiency", there is a third way in which insufficiency may arise under English law, that is, where the PSA does not know how to determine whether a particular product or process is within or outside the scope of the claim, even after employing the common general knowledge and applying the normal process of claim construction (see *Generics [UK] Ltd (t/a Mylan) v Yeda Research and Development Co Ltd and another* [2012] EWHC 1848 (Pat) ("*Generics v Yeda (HC)*"), approved in *Generics [UK] Ltd (t/a Mylan) v Yeda Research and Development Co Ltd and another* [2013] EWCA Civ 925 ("*Generics v Yeda (CA)*") at [78]; *Unwired Planet International Ltd & Ors v Google Commerce Ltd (2016)* [2016] EWHC 576 (Pat) ("*Unwired*") at [163]). English courts previously labelled this type of insufficiency as "ambiguity" (see for example, *Zipher* at [374] and *Unwired* at [149]). However, Floyd LJ and Lewinson LJ in *Anan* (at [24]–[25] and [101])

considered this is a misnomer, because "ambiguity" usually refers to a situation where words in a claim are capable of more than one meaning, but this in itself does not render the claim invalid if the normal process of claim construction through the eyes of the PSA can resolve this issue. In place of the term "ambiguity", Floyd LJ and Lewinson LJ held that the term "uncertainty" more accurately described this third type of insufficiency.

119 Uncertainty is a distinct objection from classical insufficiency. The latter is concerned with whether the patent specification sufficiently teaches the PSA how to obtain the product or work the process that is the subject of the claim, while the former is concerned with whether the PSA, *after following the teachings in the patent specification*, can tell whether the product obtained, or process worked, falls within the scope the claim. This distinction is illustrated by the facts of *Kirin-Amgen*, the first House of Lords decision to recognise uncertainty as a species of insufficiency. There, claim 19 of the patent was to a recombinant erythropoietin ("rEPO") made by a specified process with, amongst other characteristics, a higher molecular weight than urinary erythropoietin ("uEPO") (at [14]):

> Claim 19 is for—
>
> 'A recombinant polypeptide having part or all of the primary structural conformation of human or monkey erythropoietin as set forth in Table VI or Table V or any allelic variant or derivative thereof possessing the biological property of causing bone marrow cells to increase production of reticulocytes and red blood cells to increase haemoglobin synthesis or iron uptake and characterised by being the product of eucaryotic expression of an exogenous DNA sequence and which has a higher molecular weight by SDS-PAGE from erythropoietin isolated from urinary sources.'

120 The difficulty with claim 19 lay in identifying the uEPO to test against the rEPO. Different uEPOs had different molecular weights and depending on the uEPO selected as the benchmark, a particular rEPO could either be within

or outside the scope of the claim. As the specification did not disclose exactly which uEPO to use, it was impossible to determine whether a particular rEPO fell within claim 19 and the PSA was left guessing which uEPO the patentee had in mind. And, because different uEPOs had different molecular weights, the PSA would not know in advance whether any given uEPO would bring a particular rEPO within the claim. On this basis, the House of Lords, *per* Lord Hoffmann, invalidated claim 19 for insufficiency pursuant to s 72(1)(c) of the UK Patents Act 1977 (at [121]–[125], [129] and [131]). In arriving at this conclusion, Lord Hoffmann pointed out that the choice of uEPO has "nothing to do with making the invention work" (meaning that it has nothing to do with classical insufficiency) but relates to the criterion against which one tests whether a particular rEPO falls within the claims (at [129]).

121 In a sense, the objection of uncertainty in *Kirin-Amgen* arose from the *application* of a test prescribed by the patent. The prescribed test for ascertaining whether the claim boundary had been crossed was whether the molecular weight of a particular rEPO was higher than the molecular weight of uEPO. The uncertainty resided in how that prescribed test was to be applied, because the PSA did not know which uEPO to use as the benchmark. However, uncertainty in *which test* should be used to determine whether a particular product or process meets the characteristics specified in the claim can also sustain an objection of uncertainty in the context of insufficiency. This can be seen in *Glaxo Group Ltd and other companies v Vectura Ltd* [2018] EWHC 3414 (Pat) ("*Glaxo Group*"). The validity of five patents was in issue in that case, but for the sake of illustration, we focus only on claim 1 of one of these patents, European Patent (UK) No. 1 337 240 ("Patent 240"). Claim 1 of Patent 240 claimed a method of making composite active particles. The method involved the milling of particles of active material in the presence of particles of an additive material, such that the "particles of additive material become

fused to the surface of the particles of active material" (at [86]). The patent contained very little guidance as to how the PSA was to determine whether the specified process had produced composite active particles with additive particles fused to the surface of the active particles (at [177]). The patent proprietor's expert gave evidence that the PSA could carry out electron dispersive X-ray spectroscopy ("EDX") to cross-check if this was the case, but Arnold J rejected this for two reasons. First, he found that a patent is insufficient if the technique for determining whether a particular product or process falls within the scope of the claims is not mentioned in the patent specification and is not part of the PSA's common general knowledge. On the facts, EDX could not save the patent from insufficiency because the relevant test was not mentioned in the patent specification and was not part of the PSA's common general knowledge even though it existed at the priority date (at [180]). Second, EDX had limitations which made it unsuitable for determining whether the product or process in question had the characteristic called for by the claim. The patent proprietor had also failed to validate the use of EDX for this purpose (at [181]). Arnold J therefore found that Patent 240 was invalid for insufficiency on the basis that it did not enable the PSA to determine whether a process or product fell within the claim (at [176] and [181]).

122 Whilst uncertainty as a type of insufficiency is well-established in English patent law, it has not been expressly recognised under Singapore patent law. The possibility of uncertainty giving rise to insufficiency was only contemplated in passing in *First Currency Choice* at [72], where we said:

> [W]here there is insufficient disclosure of the invention in the specification as a result of an ambiguous or meaningless claim, the invention itself may not be properly enabled, and revocation under s 80(1)(*c*) of the [Patents] Act may still be possible.

This proposition rested on two authorities: Simon Thorley *et al*, *Terrell on the Law of Patents* (Sweet & Maxwell, 16th Ed, 2006) ("*Terrell 16th*") at para 7-106 and *Kirin-Amgen* at [124]–[129], both of which recognise uncertainty (which is referred to as "ambiguity" in *Terrell 16th* at para 7-106) as an objection against the sufficiency of a patent.

123 On the facts, the appellant's case relating to the Metripol Uncertainty Problem is in essence an objection of uncertainty. The Judge considered and rejected the appellant's *factual* contention that the PSA in this case would not know how to tell when the δ value of the single crystal CVD diamond remains in the SG 872 First Order (*Judgment* at [200]–[206]), but did not comment on whether Singapore patent law does or should recognise uncertainty as a distinct type of patent insufficiency. On appeal, the appellant urges us to hold, as a matter of Singapore patent law, that a claim is insufficient if it is uncertain such that the PSA will not know whether he is inside or outside the claim.[110]

124 In our judgment, where a PSA does not know how to determine if a particular product or process is within the scope of the claim even after employing his common general knowledge and the normal claim construction process, the sufficiency requirement in ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed) is not satisfied. We refer to this as uncertainty. Insufficiency remains a single ground of revocation embodied in s 80(1)(*c*) of the Patents Act (2005 Rev Ed), but it may arise in at least two distinct ways: classical insufficiency and uncertainty. We arrive at this view for three reasons.

125 First, as a matter of logic, a PSA can only be said to know how to perform the invention, if he knows what steps he needs to take to arrive within

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110 AC at para 150.

the claimed invention *and* knows how to determine if he has in fact obtained a product or worked a process within the scope of the claimed invention. It is meaningless for the PSA to know the former, meaning what steps he must take, if he does not also know the latter, meaning whether he has successfully taken those steps and made the invention. As Birss J said in *Unwired* at [159], the problem in *Kirin-Amgen* was that there was "a failure to disclose the invention clearly enough for it to be performed ***at all*** because the [PSA] could never know if they were within it or not" [emphasis added in bold italics].

126 Second, the sufficiency requirement seeks to ensure that others would be able to work the invention and benefit from it when it falls into the public domain following the expiry of the patent. But what benefit is there to the public if even the PSA does not know whether he is working the invention? In such circumstances, the inventor/patentee has not fulfilled his end of the patent bargain and ought to be denied a limited-term monopoly over the claimed invention.

127 Third, a patentee filing a patent application is in essence asking the State to grant it a property right. This much is recognised in s 41(1) of the Patents Act (2005 Rev Ed):

> 41.—(1) ***Any patent or application for a patent is personal property (without being a thing in action)***, and any patent or any such application and rights in or under it may be transferred, created or granted in accordance with this section.
>
> [emphasis added in bold italics]

It therefore behoves the patentee to properly define when that property right has been infringed so that others would know how not to trespass. As Lewison LJ in *Anan* said at [99]:

> A patent is personal property, without being a chose in action. We know that because section 30 (1) of the Patents Act 1977

> tells us so. The essence of a right of property is that it distinguishes between what is mine and what is not mine. So there needs to be a boundary. If someone crosses the boundary, he invades my property right. The function of the claims is to delineate that boundary. As Lord Russell put it in *Electrical & Musical Industries v Lissen Ltd* (1939) 56 RPC 23, 39:
>
> > 'The function of the claims is to define clearly and with precision the monopoly claimed, so that *others may know the exact boundary of the area within which they will be trespassers*.'
>
> [emphasis added]

128 Similar sentiments were echoed by the High Court in *Rohm* at [102]:

> … A patent is a property right. It is for the patentee to clearly set out and define the subject-matter over which the property right is claimed (see s 25(5) of the Patents Act). The words and expressions used are the patentee's alone. It is by reference to the specifications that members of the public determine the boundaries of the claimed property right. …

A patentee has not properly defined the extent of his property right if a PSA does not know how to ascertain when a particular product or process constitutes the subject matter over which the property right is claimed. Much uncertainty would be engendered if the law were to grant or recognise the asserted monopoly in such circumstances.

129 We turn to consider the respondent's submission that the Judge, on the basis that lack of clarity under s 25(5)(*b*) of the Patents Act (2005 Rev Ed) was not a ground for revocation, rejected the appellant's argument on insufficiency arising from "ambiguity".[111] The respondent further suggests that the acceptance of the appellant's argument on insufficiency by uncertainty requires a departure

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111 RC at para 173; RSA at para 50.

from the position at law that the failure to comply with the clarity requirement is not a basis for revocation.[112]

130 We disagree with the respondent's interpretation of the Judge's reasoning. The Judge was aware that the appellant's arguments on the Metripol Uncertainty Problem went towards the issue of sufficiency instead of clarity (see Judgment at [192]–[197]), and she did not dismiss the appellant's arguments on the basis that lack of clarity is not a ground for revocation.

131 More importantly, the respondent's submissions raise the need to clarify the distinction between insufficiency arising from uncertainty for the purposes of ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed), and lack of clarity for the purpose of s 25(5)(*b*) of the Patents Act (2005 Rev Ed). This distinction is important, because the former is a ground for revoking a patent once granted while the latter is not (see *Ng Kok Cheng* at [74] and *First Currency Choice* at [72]). The test for clarity is whether the PSA can understand the words used in the claims. In this regard, there is no need to remove all conceivable doubt as to the meaning of the claims, but the claims must be as clear as the subject matter reasonably permits (see *The Modern Law of Patents* at para 4.133, citing *Chevron Research Company's Extension* [1975] FSR 1 at 13 and *LG Philips LCD v Tatung (UK)* [2007] RPC 21 at [20]). A lack of clarity in the claim's language, however, does not *per se* amount to uncertainty in the context of insufficiency (see *The Modern Law of Patents* at paras 4.58 and 4.132). To result in uncertainty giving rise to insufficiency pursuant to ss 25(4) and 80(1)(*c*) of the Patents Act (2005 Rev Ed), the lack of clarity in claim language must leave the PSA unclear as to how to determine whether a particular product or process is within the scope of the claim even after drawing upon his common

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112 RC at para 174.

general knowledge or applying the typical claim construction process (see *First Currency Choice* at [72]; *Martek Biosciences Corp v Cargill International Trading Pte Ltd* [2011] 4 SLR 429 at [72]; *Anan* at [24]–[25] and [101]). As we have explained above, lack of clarity under s 25(5)(*b*) of the Patents Act (2005 Rev Ed) is not the issue we are concerned with when dealing with the issue of uncertainty.

132 In the light of the foregoing discussion, we turn to consider the substantive arguments on sufficiency in the context of this case. But before doing so, we should add that while the preceding discussion (including that at [56]–[75]) referred to the 2005 Revised Edition of the Patents Act, on which the parties' claims and counter-claims are based, these views apply equally to the 2020 Revised Edition of the Patents Act 1994 because the differences between the relevant provisions in these editions are not material to the points made.

Whether any or all of the claims in SG 872 are invalid due to classical insufficiency

Whether Claim 62 is classically insufficient

133 The appellant submits that Claim 62 presents the PSA with "a classic undue burden" as he is faced with a research project to find out what Other Growth Conditions are necessary to obtain a specific type of SG 872 Diamond.[113] To evaluate the appellant's submission, it is necessary to understand when a PSA is saddled with an "undue burden" to work the invention.

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113 ASA at para 28 n 40, para 39; AR at para 44.

(1) What is an "undue burden"

134 To re-capitulate, the patent specification need not set out every detail necessary for performance, including what is self-evident or part of common general knowledge, and can leave the PSA to use his skill to perform the invention (*First Currency Choice* at [62]; *Ng-Loy* at para 30.3.4). However, the PSA must be able to perform the invention "without prolonged research, enquiry and experiment" (*Halliburton Energy Services Inc v Smith International (North Sea) Ltd and others* [2006] EWCA Civ 1715 at [13]; see also *Susanna Leong* at para 16.273). An oft-cited passage from the judgment of Aldous J in *Mentor Corporation and another v Hollister Incorporated* [1991] FSR 557 at 562 explains the point as follows (see *Terrell* at para 13-18):

> The section requires the skilled man to be able to perform the invention, but does not lay down the limits as to the time and energy that the skilled man must spend seeking to perform the invention before it is insufficient. Clearly there must be a limit. The subsection, by using the words, clearly enough and completely enough, contemplates that patent specifications need not set out every detail necessary for performance, but can leave the skilled man to use his skill to perform the invention. In so doing he must seek success. He should not be required to carry out any ***prolonged research, enquiry or experiment***. He may need to carry out the ***ordinary methods of trial and error, which involve no inventive step*** and generally are necessary in applying the particular discovery to produce a practical result. In each case, it is a ***question of fact***, depending on the nature of the invention, as to whether the steps needed to perform the invention are ordinary steps of trial and error which a skilled man would realise would be necessary and normal to produce a practical result.
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> [emphasis added in bold italics]

135 As we noted in *First Currency Choice* at [60], "[i]t would not be desirable, and, indeed, probably quite impossible, to lay down any hard-and-fast rule" as to the required degree of clarity and completeness to satisfy the requirement for sufficiency of disclosure. The amount of teaching required in the specification may vary from invention to invention (*Mentor Corporation*

and another v Hollister Inc [1993] RPC 7 at 11, cited in *Susanna Leong* at para 16.281).

136 Further, the examples in the patent specification may be taken into account when determining whether there is sufficiency. This is self-evident from the Patents Act (2005 Rev Ed) and Patents Rules. Section 80(1)(*c*) of the Patents Act (2005 Rev Ed) provides that the "specification" of the patent must "disclose the invention clearly and completely". And s 25(3)(*b*) of the Patents Act (2005 Rev Ed), read with rr 19(3) and 19(5)(*e*) of the Patents Rules, shows that the specification must contain a description of the invention, which may itself include *examples* where appropriate. It was also recognised in *Eli Lilly and Co v Human Genome Sciences Inc* [2008] EWHC 1903 (Pat) at [239] that sufficiency must be assessed "on the basis of the specification as a *whole* including the description and the claims" [emphasis added] (see also *Pacific Biosciences of California, Inc's Applications* BL O/500/18 at [43], cited in *CIPA Guide to the Patents Act* (Paul Cole & Richard Davis eds) (Sweet & Maxwell, 9th Ed, 2022) at para 14.28).

(2) Does Claim 62 impose an undue burden on the PSA trying to work it?

137 In light of the foregoing principles, the question before us is whether Claim 62 enables a PSA to perform the *entire breadth* of the claim without an undue burden. In summary, we consider that Claim 62 *does* impose an undue burden on the PSA because:

(a) The Other Growth Conditions do affect the quality of the CVD diamond produced.

(b) The specification of SG 872 (including the examples therein) merely provides a starting point for an onerous research programme:

(i) The patent specification does not teach the PSA how to determine where within a range of values he should operate, in respect of each of the Other Growth Conditions, so as to produce an SG 872 Diamond with a particular property or combination of properties.

(ii) Calibrating the value of each Other Growth Condition is complex because these conditions and the appropriate nitrogen concentration in the source gas are interrelated.

(iii) The CVD growth process and the resulting diamond are sensitive to changes in the Other Growth Conditions.

(iv) The authorities show that providing discrete examples of sets of values of the Other Growth Conditions, and the corresponding quality of the diamond produced, does not provide enabling disclosure across the entire breadth of the product claims, each of which asserts a monopoly over a range of products.

(c) Experimental data, while not adduced in this case, is not necessary to ground a classical insufficiency challenge.

(d) The respondent has not proved that the manner of calibrating the Other Growth Conditions in order to produce a CVD diamond of a particular quality forms part of the common general knowledge which need not be taught by SG 872.

We elaborate on these points.

(A) OTHER GROWTH CONDITIONS AFFECT THE QUALITY OF THE CVD DIAMOND PRODUCED

138 Claim 62 states that the process taught therein enables the production of "a CVD single crystal diamond material meeting the requirements of ***one or more of*** claims 1 to 61" [emphasis added in bold italics].[114] To provide sufficient enablement across its *entire* breadth, Claim 62, read with the specification of SG 872, must teach the PSA to produce every diamond falling within each of the product claims in SG 872 (which themselves cover a range of diamonds), or *any* combination of the product claims.

139 According to the appellant, the gap in SG 872 is that it fails to specify the Other Growth Conditions that should be applied in order to produce a diamond meeting the requirements of a particular product claim or a combination of product claims. The implicit premise of the appellant's argument is that the Other Growth Conditions do affect the quality of the CVD diamond produced, and this in turn affects whether the single crystal CVD diamond falls into one or more of the product claims in SG 872.

140 We deal first with this implicit premise. In our judgment, the fact that the Other Growth Conditions do affect the quality of the CVD diamond produced is evidenced by both parties' experts.

141 The respondent's expert, Dr Newton, accepted that "under high gas flow conditions the gas flow could have an effect on the *chemistry of the [growth] process*" [emphasis added].[115] As noted at [47] above, "gas flow" is one of the Other Growth Conditions. Dr Newton's oral testimony, when asked about

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114 BOM at p 374.

115 Newton-2 at para 151 (II ACB 204).

whether a PSA following SG 508 and SG 872 will end up with the same diamond, is particularly illuminating. He said that while the nitrogen ranges taught in the two patents overlap "it is not sufficient just to look at one of the parameters. You must look at the methane, the hydrogen, the flow rates, the temperature, the pressure. It's a *sensitive process*. You *start changing one of those and you go into a different regime of growth*"[116] [emphasis added]. Dr Bergonzo, another of the respondent's experts, also testified that higher gas flows could reduce the effectiveness of *in-situ* etches in removing subsurface damage and thus reducing strain in the grown layers.[117] On the appellant's side, Dr Nebel similarly recognised that "[t]he gas flow around the substrate as well as the plasma exposure affect the growth of diamond significantly."[118]

142 Aside from the expert evidence, it is the respondent's own submission that following the growth process in SG 508 will *not* inevitably lead to a diamond fulfilling the parameters of Claim 1iii) because of, among other things, differences between the Other Growth Conditions in SG 508 and SG 872.[119] In other words the respondent accepts that the Other Growth Conditions *do* influence the quality of the diamond produced. For context, SG 508 teaches the conversion of a coloured single crystal CVD diamond to another colour under heat treatment (referred to as annealing).[120] As part of its case that Examples 4 and 6 of SG 508 anticipate Claim 62, the appellant submits that the growth processes taught in SG 508 and Claim 62 overlap. A table produced by Dr

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116 Transcript, 7 August 2019, pp 100:18–101:3 (III(D13) ROA 105–106); RCN at para 49(b)(iii).

117 Dr Bergonzo's 2nd Report ("Bergonzo-2") at para 227 (I RSCB 202)

118 Nebel-1 at para 141 (III ACB 43); RSA at para 36(b).

119 RC at paras 86–88.; see also Plaintiff's outline of oral reply in second tranche of trial at para 88 (III(G6) ROA 199); PCS2 at para 1331 (III(G3) ROA 239).

120 RCN at para 47; BOM at p 213.

Nebel,[121] and adapted by the appellant, helpfully summarises the overlap (emphases by appellant omitted):[122]

Essential integer of Claim 62 of SG 872	**Disclosure in SG508 and [its priority document, GB 0220772.8 or "GB 772"]**
A substrate [with a] density of defects at the surface ... below 5 x 10^3/mm^2	... Page 14 of SG508 "The preferred low density of defects is such that the density of surface etch features related to defects, as described above, are below 5 x 10^3/mm^2, and more preferably below 10^2/mm^2"[123]
The substrate undergoes a plasma etch on the surface	... page 15 of SG508: "One specific method of minimising the surface damage of the substrate, is to include an *in situ* plasma etch on the surface on which the homoepitaxial diamond growth is to occur."[124]
A provision of a source gas and dissociating the source gas to produce a synthesis atmosphere which contains 300 ppb to 5 ppm calculated as molecular nitrogen	page 7 of SG508: "In order to achieve reproducible results and tailor the final product the N in the process needs to be controlled. Typical concentrations in the gas phase are 0.5 ppm – 500 ppm, more preferably 1 ppm – 100 ppm, and more preferably 2 ppm to 30 ppm."[125]
	Page 34 of SG 508:"the gas mixture included 2.5 ppm of nitrogen"[126]
	Page 36 of SG 508:"the gas mixture included 3.8 ppm of nitrogen"

121 Nebel-1 at para 668 (III(B14) ROA 22–23).

122 AC at para 60.

123 BOM at pp 223 (SG 508), 374 (Claim 62).

124 BOM at pp 224 (SG 508), 374 (Claim 62).

125 BOM at pp 216 (SG 508), 374 (Claim 62); see also AC at para 60.

126 BOM at pp 243 (Example 4), 245 (Example 6).

In an attempt to distinguish the growth process in SG 508 from that in SG 872, the respondent, as stated at the start of this paragraph, argued that while the nitrogen concentrations used in Examples 4 and 6 of SG 508 (and the nitrogen range in SG 508, generally) fall within or overlap with the Claim 62 Nitrogen Range, there are "a lot of differences in terms of gas flow, temperature and methane concentration" and that therefore, following Examples 4 and 6 will not inevitably lead to an SG 872 diamond. This clearly shows the materiality of the Other Growth Conditions.

143 We therefore accept that the Other Growth Conditions do affect the strain in the diamond that is eventually grown and that it is necessary for the PSA to determine the *precise* values of the Other Growth Conditions to use in order to grow a CVD diamond of a particular quality.

(B) SPECIFICATION OF SG 872 MERELY PROVIDES A STARTING POINT FOR AN ONEROUS RESEARCH PROGRAMME

144 We now turn to consider the guidance the patent specification gives in respect of the Other Growth Conditions, to determine whether the PSA is faced with an undue burden of ascertaining the precise values to use.

145 We begin with some general observations on the process claims and relevant portions of the patent specification. None of the process claims provides directions on the precise values the PSA should use for the Other Growth Conditions, so as to produce diamonds with particular characteristics satisfying one or more of the product claims. As we shall see, this conclusion remains unchanged even after the process claims are read in the context of the entirety of SG 872, in particular the examples.

146 The description in the patent specification indicates ***ranges*** of values for *some* of the Other Growth Conditions:

(a) High gas pressure: 50–500 x 10^2 pascals ("Pa"), and preferably 100–450 x 10^2 Pa.[127]

(b) High plasma power density, resulting from high microwave power (typically 3–60kW, for substrate diameters of 25–300mm).[128]

Regarding temperature, the specification of SG 872 provides no guidance on the appropriate atmospheric temperature or substrate temperature to use during the growth process. It merely notes that a process called "annealing", in which elevated temperature is used in a controlled manner to bring about a beneficial modification to any property of diamond, may be *combined* with the "diamond of the invention" to enhance specific properties. Annealing takes place between 1200°C and 2800°C.[129] However, this temperature range in relation to annealing say nothing about the temperature conditions that should be applied in the process claims of SG 872.

147 Additionally, the patent specification identifies one main set of ***specific*** values for the Other Growth Conditions in Example 1 (the "Example 1 Other Growth Conditions"). The same values are used in the other 14 examples in SG 872, subject to modifications to the gas pressure in Examples 9 and 14 and the concentration of methane in Example 14.

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127 BOM at p 319.

128 BOM at p 319.

129 BOM at pp 319–320.

148 In Example 1, 1ppm nitrogen was used together with these Other Growth Conditions:[130]

> 1) The ***2.45 GHz reactor*** was pre-fitted with point of use purifiers, reducing unintentional contaminant species in the incoming gas stream to below 80 ppb.
>
> 2) An *in situ* oxygen plasma etch was performed using ***15/75/600 sccm*** (standard cubic centimetre per second) of $O_2/Ar/H_2$ at ***263 x 10^2 Pa*** and a substrate temperature of ***730°C***.
>
> 3) This moved without interruption into a hydrogen etch with the removal of the O_2 from the gas flow.
>
> 4) This moved into the growth process by the addition of the carbon source (in this case CH_4) and dopant gases. In this instance was ***CH_4 flowing at 36 sccm*** and ***1 ppm N_2*** was present in the process gas, provided from a calibrated source of ***100 ppm N_2*** in H_2 to simplify control. The substrate temperature at this stage was ***800°C***.
>
> [emphasis added in bold italics]

To summarise, the Example 1 Other Growth Conditions teach the use of: (a) a 2.45 GHz reactor; (b) gas flow of 15/75/600 sccm for $O_2/Ar/H_2$, and 36 sccm for CH_4; (d) pressure of 263 x 10^2 Pa; and (e) substrate temperature of 730°C during *in situ* etching, and 800°C during growth. The parties also agree that Example 1 teaches the use of 5% of CH_4 in the source gas.[131] SG 872 does not expressly state which claim(s) the resulting diamond satisfies, although it appears to fulfil at least Claim 1v). This is because the diamond grown "had a FSR of 1.6678±2x$10^{-4}$$cm^{-1}$" and Claim 1v) covers diamonds with a FSR which varies by less than 5 x 10^{-3} cm^{-1}.[132]

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130 BOM at p 339.

131 Nebel-1 at para 1262 (III(B14) ROA 159); PCS2 at para 1329 (III(G3) ROA 238).

132 BOM at pp 340, 364.

149 Example 9 introduced a variation to the gas pressure. It shows that using *5ppm* of nitrogen with – (a) the Example 1 Other Growth Conditions or (b) the Example 1 Other Growth Conditions, *save* that the gas pressure is 210 x 10^2 Pa – yields an SG 872 diamond. While not expressly stated, it appears that the diamonds grown under Example 9 satisfy Claims 16i) and 17 of SG 872. The optical scatter of the diamonds falls within the ranges defined in these claims.[133]

150 Example 14 shows that using the Example 1 Other Growth Conditions with modifications to either gas pressure or methane – (a) 5ppm of nitrogen with *330 x 10^2 Pa* gas pressure or (b) 2.5ppm nitrogen with *3.5% CH_4* – yields an SG 872 Diamond. The diamond grown under (a) is referred to as "E14.1", while the diamond grown under (b) is "E14.4". While not expressly stated, it appears that the optical absorption of E14.1 and E14.4 falls within the range defined in Claim 19.[134]

151 With this context in mind, we now arrive at the heart of the issue – whether the need to determine the Other Growth Conditions places an undue burden on the PSA to work the entire breadth of Claim 62. Having reviewed the evidence, we answer this question in the affirmative for the following reasons.

(I) GUIDANCE IN PATENT SPECIFICATION (INCLUDING EXAMPLES) IS LIMITED

152 First, the guidance on the Other Growth Conditions provided in SG 872 – both the ranges of values provided in the specification (see [146] above) and Examples 1, 9 and 14 – is inadequate.

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133 BOM at pp 353, 367.

134 BOM at pp 360, 367.

153 With regard to the ranges of values, these only concern *two* variables: "gas pressure" and "plasma power density". There is no such guidance on other variables such as gas flow, temperature and the concentration of the remaining gases in the source gas. And even, for the ranges provided, there is no teaching on how to determine where within the range the PSA should operate so as to produce a CVD diamond with a particular characteristic or combination of characteristics.

154 The respondent argues that Example 1, read with Example 9, gives "full disclosure of the reactor conditions such as temperature, pressure and gas flow rates".[135] We disagree. The Example 1 Other Growth Conditions, even when read with Example 9, only disclose the Other Growth Conditions to be used with 1ppm and 5ppm of nitrogen to produce *three* variants of an SG 872 diamond. These three variants are differentiated by the growth conditions used to produce them: (a) Example 1 Other Growth Conditions with 1ppm nitrogen (Example 1); (b) Example 1 Other Growth Conditions with 5ppm nitrogen (Example 9); and (c) Example 1 Other Growth Conditions, save for a gas pressure of 210 x 10^2 Pa, with 5ppm nitrogen (Example 9). These examples in no way enable the PSA to know what values of the Other Growth Conditions to use to produce diamonds falling within *all* of the 68 product claims in SG 872 either individually, or in *any* combination of the product claims. This deficiency remains even when Example 14 is taken into account. This example merely introduces two other variations to the Example 1 Other Growth Conditions – a gas pressure of 330 x 10^2 Pa with 5ppm nitrogen, and 3.5% CH_4 with 2.5ppm nitrogen.[136]

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135 RCN at para 51(c).

136 BOM at p 360.

(II) CALIBRATING THE OTHER GROWTH CONDITIONS IS A COMPLEX PROCESS

155 Second, and crucially, the determination of the specific values of the Other Growth Conditions to use in order to produce a diamond of a particular quality is a *complex* process. The Other Growth Conditions and the nitrogen concentration in the source gas are interrelated. The specification of SG 872 reveals that *several* of the Other Growth Conditions affect the appropriate concentration of nitrogen to be used. SG 872 pertinently states that the concentration of nitrogen to be used in the growth process is "a *sensitive* function of the growth conditions, *including* temperature and pressure" [emphasis added].[137] The specification adds that the limits to the concentration of nitrogen to be used "are process dependent, such that they may vary according to the process conditions used, including the actual gaseous source of N, and also the ***specific material properties required***, and are best illustrated by way of example" [emphasis added in bold italics].[138] Yet, there is no exposition on the nature of the relationships between the Other Growth Conditions and the appropriate nitrogen concentration, or how these relationships should be taken into account when determining the values of the Other Growth Conditions. The specification also recognises that the relationships between nitrogen concentration and the Other Growth Conditions are "best illustrated by way of example", but, in our judgment, fails to deliver on that promise (for reasons given at [154] above). Instead, the PSA is left to undertake extensive research to uncover the relationships between the variables in the growth process depending on the physical properties sought in the diamond grown.

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137 BOM at p 314.

138 BOM at p 314.

(III) GROWTH PROCESS IS SENSITIVE TO CHANGES IN THE OTHER GROWTH CONDITIONS

156 Third, to compound matters, the *entire* growth process and the resultant diamond material are *sensitive* to changes in any of the Other Growth Conditions. It is not as though the PSA can vary the Other Growth Conditions without any material consequences to the quality of the diamond produced. This point is elucidated in Dr Newton's oral testimony. He stated that the growth process is "sensitive" in the sense that a change to *one* variable will result in a "different regime of growth" altogether (see above at [141]). Dr Newton's evidence coheres with the specification of SG 872, which states that the appropriate concentration of nitrogen is a "*sensitive* function of the growth conditions" [emphasis added].[139]

157 The upshot of all of this is that the PSA is unduly burdened with the need to experiment with *innumerable* combinations of Other Growth Conditions across the *entire* nitrogen range in Claim 62, so as to determine which combination will result in a diamond meeting the desired product claim(s). This is an *onerous* research programme because there are *many* values for each variable to experiment with, all while balancing the (undefined) relationships between the Other Growth Conditions and appropriate nitrogen concentration. Without any adequate teaching of a principle of general application or unifying characteristic that can guide the PSA to determine the appropriate value of each of the Other Growth Conditions, the PSA must resort to a prolonged trial and error experiment, fraught with uncertainty and unpredictability, using arbitrarily selected values for each variable in the growth process.

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139 BOM at p 314.

(IV) AUTHORITIES HIGHLIGHT THE INSUFFICIENCY OF PROVIDING A STARTING POINT FOR AN ONEROUS RESEARCH PROGRAMME

158 Based on the foregoing, Examples 1, 9 and 14, as well as the ranges of values for gas pressure and plasma power density in the description, at best provide a starting point for an onerous research programme.

159 The case law holds that an *undue* burden is imposed if this is all that the patent's specification affords.

160 In *Bayer Schering Pharma/Reach-through claim* [2009] OJ EPO 516 ("*Bayer*"), the patent in suit was for the use of compounds, which are capable of "stimulating the soluble guanylate cyclase independently of the heme group in the enzyme, to manufacture medicaments for the treatment of cardiovascular disorders". The patent was held to be insufficient under Art 83 of the European Patent Convention because "compounds" was not defined by any chemical structure, but solely by the functional ability to "stimulate guanylate cyclase". Article 83, similarly to s 25(4) of the Patents Act (2005 Rev Ed), requires the invention to be stated "in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art." The Technical Board of Appeal ("Board") held that trial and error on "every conceivable chemical compound" for the claimed capability was an undue burden. It also noted that "the simple structural identification of one suitable compound class of general formula" would not help the PSA. By analogy, the provision by Example 1 in SG 872 of a *baseline* for a research project cannot cure Claim 62 of insufficiency. We therefore agree with the appellant that the examples in SG 872 "cannot support a claim of the breadth of claim 62".[140] It is useful to reproduce the relevant portion of the Board's reasoning in full (at [5.2]):

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140 AR at para 46; see also Transcript, 20 January 2022, p 61:10.

> .. not all conceivable compounds possess the capability of stimulating the soluble guanylate cyclase independently of the heme group in the enzyme as required by the claim, and it is up to the skilled person to pick from this indefinite and innumerable host of alternatives the suitable ones. In order to pick from that host the skilled person cannot draw on his common knowledge to identify from the host of possible alternatives those suitable chemical compounds which, along with the compounds of general formula (I) exemplified in the application in suit, are also covered by the functional definition in the claim, because the application in suit (p.1, ll.5 and 6) discloses that the invention is based on a 'new mechanism of action'. In selecting the chemical compounds possessing the necessary capability, all he has to rely on is the information provided in the application in suit. In ***the absence of any selection rule in the application in suit***, not even in the form of a structure activity relationship on the basis of which he could identify from the outset suitable compound classes, the skilled person must resort to trial-and-error experimentation on arbitrarily selected chemical compounds using the screening method cited in the application in suit to identify within the host of possible alternative compounds those which stimulate the soluble guanylate cyclase independently of the heme group in the enzyme. Nor does he have any information at his disposal in the application in suit leading necessarily and directly towards success through the evaluation of initial failures. ***Nor would the simple structural identification of one suitable compound class of general formula (I) in the application in suit be of any help to the skilled person***. To find all the suitable alternatives, he would therefore have to test every conceivable chemical compound for the claimed capability; this represents for the skilled person an invitation to perform a research programme and thus an undue burden.
>
> [emphasis added]

161 Aldous LJ's *obiter dictum* in *American Home Products Corporation v Novartis Pharmaceuticals UK Ltd* [2001] RPC 8 equally emphasises the inadequacy of supplying a starting point for a research programme (cited in *Terrell* at para 13-25). The patent in suit there was for the "[u]se of rapamycin for the preparation of a medicament for inhibiting organ or tissue transplant rejection in a mammal in need thereof" (at [5]). A competitor produced a derivative, which gave rise to the issue of whether the derivative fell within the scope of the claim. The English Court of Appeal held that the claim did not

extend to derivatives but considered the position of insufficiency under s 72(1)(c) of the UK Patents Act 1977 in the event it did. Aldous LJ opined that the patent would be insufficient because, as the judge had found below, the number of possible derivatives was "vast" and many would *not* exhibit the required immunosuppressant activity. As a result, "whether any particular molecule derived from rapamycin would work at all was impossible to predict with certainty" (at [42]–[43]):

> 42. The judge held that the number of possible derivatives was vast and whether any particular molecule derived from rapamycin would work at all was impossible to predict with certainty. *Many derivatives would not exhibit immunosuppressant activity*. Those which involved small changes to the side chain would be the most likely to work. Thus the skilled person could make up a list of possibles, with those believed to be the most likely at the top of the list. Even so, finding appropriate derivatives, if they existed, would involve a ***systematic and iterative process***. Further, when a derivative which had appropriate activity had been identified, it would be impossible to be certain that it did not exhibit unpredictable defects. To discover whether it did would require further tests which would take a long time.
>
> 43. The very *uncertainty and unpredictability* found by the judge meant that the skilled person was being required to carry out research. The duty upon the patentee is to provide a description which enables the skilled person to perform the invention, in this case across the breadth of the claim; ***not to supply a starting point for a research programme***. If the claim includes derivatives of rapamycin, an enabling description of such derivatives is needed so that the products of the claim can be ascertained.
>
> [emphasis added in italics and bold italics]

162 So too is the case of *Amorphous silica/INEOS* T 1743/06 ("*Amorphous Silica*") on point. The patent there was found to be insufficient as the process claim for producing amorphous silicas according to the product claims involved variables which the PSA was not taught to calibrate. Similar to the present case, the product claims for "amorphous silica" were characterised by a series of physical properties. For reference, the process claim stated as follows:

> 18. Process for the production of amorphous silicas according to claims 1 to 17 comprising:
>
> − adding a 17.0 to 21.5% solution of 2.1 to 2.5 Molar Ratio silicate solution to water,
>
> − then further adding a 17.0 to 21.5% solution of 2.1 to 2.5 Molar Ratio silicate solution together with a 15 to 20% sulfuric acid solution, over a period of over 40 minutes at such flow rates that the pH is maintained in the range from 8.0 to 9.0,
>
> − then aging the resultant slurry for a period of 0 to 30 minutes at a temperature of 90 to 100°C,
>
> − doing a second addition of a 15 to 20% sulfuric acid solution to bring the pH down to pH 3 to 5,
>
> − aging the resulting slurry for a period of 0 to 20 minutes at pH 5 at a temperature of between 90 and 100°C,
>
> − adjusting the pH to pH 3.5 to 5, and
>
> − eventually filtering, washing and drying the final slurry.

163 The patent contained two examples of specific amorphous silicas possessing characteristics that fell within the ranges of values defined under the product claim (at [1.2]). In respect of the process claim, the Board noted as follows:

> 1.3 Concerning the preparation of the amorphous silicas disclosed in the patent in suit, there is the information at paragraphs [0022] and [0021] that amorphous silicas presenting good cleaning characteristics without damaging teeth and which are particularly good at preventing stain formation can be obtained through a process 'comprising:
>
> − adding a 17.0 to 21.5% solution of 2.1 to 2.5 Molar Ratio silicate solution to water,
>
> − then further adding a 17.0 to 21.5% solution of 2.1 to 2.5 Molar Ratio silicate solution together with a 15 to 20% sulfuric acid solution, over a period of over 40 minutes at such flow rates that the pH is maintained in the range from 8.0 to 9.0,
>
> − then aging the resultant slurry for a period of 0 to 30 minutes at a temperature of 90 to 100°C,
>
> − doing a second addition of a 15 to 20% sulfuric acid solution to bring the pH down to pH 3 to 5,

> − aging the resulting slurry for a period of 0 to 20 minutes at pH 5 at a temperature of between 90 and 100°C,
>
> − adjusting the pH to pH 3.5 to 5, and
>
> − eventually filtering, washing and drying the final slurry'.
>
> The board however notes that the description of the contested patent does ***not give any details*** as to how the above process conditions 'for preparing amorphous silicas presenting good cleaning characteristics without damaging teeth and which are particularly good at preventing stain formation' ***might be modified in order to achieve reliably the parameters of the specific amorphous silicas defined in the claims 1 at issue***.
>
> [emphasis added in bold italics]

164 One specific issue which vexed the parties was the absence of any teaching on the appropriate stirring speed to use during the preparation of the silica. The patentee argued that the PSA could determine the appropriate stirring speed by varying it while reworking the two examples in the patent specification. However, the Board held that this did not overcome the lack of teaching for the stirring speed, and other process parameters, in respect of the *other* amorphous silicas that were *not contemplated in the examples but fell within the range of products claimed*:

> 1.8 ... The board can accept that such a trial and error experimentation might in the present case not be considered as undue burden as far as the silicas illustrated in the ***examples*** of the contested patent are concerned. However, this reasoning which can be accepted only for the two examples, ***does not hold good for the other claimed but non-exemplified amorphous silicas*** and in the absence of any specific recipe concerning the preparation of such silicas, the problems concerning the stirring speed still remain for silicas claimed over the whole range.
>
> 1.9 The skilled person is thus confronted with the uncontested fact that he has ***a lot of process variables affecting the claimed parameters, but once he has encountered failure in one parameter value, there is no clear guidance enabling him to adjust the multitude of process steps in order to arrive with certitude at silicas***

> ***meeting the parameter requirements defined in claim 1*** of both requests at issue.
>
> Even though a reasonable amount of trial and error is permissible when it comes to assessing sufficiency of disclosure, there must still be adequate instructions in the specification, or on the basis of common general knowledge, leading the skilled person ***necessarily and directly towards success***, through evaluation of initial failures. This is not the case here, since the preparation of the amorphous silicas claimed is made dependent on the adjustment of ***different process parameters for which no guidance is given in the patent in suit***, so that the broad definition of an amorphous silica as presently claimed is no more than an invitation to perform a research program in order to find a suitable way of preparing the amorphous silicas over the whole area claimed.
>
> [emphasis added in bold italics and bold italics with underline]

165 As a result, the Board in *Amorphous Silica* upheld the revocation of the patent. This reinforces our view at [160] that just providing *discrete sets* of process parameters in examples without a general or unifying principle to guide the PSA in calibrating these parameters to produce a desired product may not sufficiently enable the invention across its entire breadth. Indeed, in Claim 62, given the complexities described at [155]–[156] above, the Example 1 Other Growth Conditions and the modifications in Examples 9 and 14, do *not* avoid the need for an unduly prolonged research project.

166 Finally, *Saint-Gobain Adfors SAS (a company existing under the laws of France) v 3M Innovative Properties Co (a company existing under the laws of Delaware, United States)* [2022] EWHC 1018 (Pat) ("*Saint-Gobain*") underscores the importance of providing guidance on how to vary process parameters to achieve a *specific* product in the range of products claimed in the patent, in so far as how to calibrate the process parameters is not part of the common general knowledge. The patent contained a product claim for dish-shaped abrasive particles with, among other integers, a sloping sidewall and a specific thickness ratio. The latter was described as follows: "a thickness ratio

of Tc/Ti for the dish-shaped abrasive particles (20) is *between 1.25 and 5.00*, wherein Tc is the thickness at a corner (30) of the sidewall (28) and Ti is the smallest thickness of the interior of the first face (24)" (at [93]) [emphasis added in italics]. Abrasive products made from abrasive particles are used to abrade, cut, grind, finish or polish a variety of materials (at [13]). The "recessed or concave" face of the invention was said to allow the claimed products to remove more material, when being applied as an abrasive particle, than a flat abrasive particle (see [59]). Critically, the court held that the patent had to enable the production of particles without undue burden *across the whole range of* thickness ratios defined in Claim 1, namely 1.25 to 5.00 (at [196]). This also strengthens our construction of the product claims in SG 872 (see [83] above). As to the point on insufficiency, the court held that the patent imposed an undue burden to produce particles across the entire scope of the product claim (at [233]). Part of the patent specification stated that it was possible to produce particles with thickness ratios between 1.55 to 2.32 (at [68] and [211]). But the court was not convinced that the PSA could produce particles at the *upper* end of the defined range of thickness ratios (that is, approaching 5.00) without an undue burden. The patent provided no indication of how to adjust relevant process parameters to vary the thickness ratio across the range of the claim (at [212] and [233]). For instance, one step in the production process involved drying a wet gel that had been prepared (at [36]). While the patentee's expert argued that in order to control the Tc/Ti ratio, the PSA would increase the temperature and hence the "drying rate" of the wet gel, the court held that the PSA would not have thought to do so (at [217]). Claim 62 is likewise deficient for failing to provide adequate guidance on how to produce diamonds across the *entire* range of each product claim.

(C) EXPERIMENTAL DATA IS UNNECESSARY

167 In the present case, it is also no answer for the respondent to point to the appellant having failed to perform experiments to support its case on insufficiency. In *Novartis AG v Johnson & Johnson Medical Ltd* [2011] ECC 10, which concerned a patent for extended wear contact lenses, the English Court of Appeal upheld the lower court's finding that the patent was insufficient because it did not teach which materials within the specific families and examples described were suitable for the production of ophthalmically compatible extended wear lenses. Neither did the patent enable the PSA to predict whether any lens is likely to be opthalmically compatible over a period of extended wear (at 195). Crucially, the court held that it was "irrelevant" that the challenger had not performed any experiments. As observed by Jacob LJ, the more important point was that (at 196):

> ... the Patent gives no clue as to whether he will be successful. If he happens to have chosen a pair of polymers and proportions which 'work' that will be his ***luck, not something contributed by the Patent***. And even if he is lucky, that luck will tell him ***nothing about the whole of the remaining vast area*** claimed. The Patent is manifestly not enabling across the range claimed.
>
> [emphasis added in bold italics]

168 In much the same way, we do not need experimental data to conclude that the patent tells the PSA nothing about how to obtain the appropriate combination of the Other Growth Conditions and nitrogen concentration to grow a single crystal CVD diamond material with characteristics satisfying one or more of the product claims. The PSA attempting to perform Claim 62 may by happenstance stumble on the appropriate combination and grow the low-strain diamond desired, but such a result is *not* due to the teaching in SG 872. It is clear from the face of SG 872's specification that any success the PSA has in performing Claim 62 will be due to his own luck and efforts. In these

circumstances, it would be unfair to allow a patentee to take credit for something the patent does not sufficiently enable and which requires the PSA to expend undue effort to uncover.

(D) CALIBRATING THE OTHER GROWTH CONDITIONS IS NOT COMMON GENERAL KNOWLEDGE

169 We turn to consider whether the PSA, imputed with common general knowledge, would know how to calibrate all the Other Growth Conditions. In so doing, we will deal with two points that were raised by the respondent and the Judge respectively.

170 The respondent argues that the PSA "would know to adjust the regular reactor conditions such as temperature and gas flow rates".[141] Knowledge that the Other Growth Conditions *do* affect the quality of the diamond grown may have been part of the common general knowledge. But that is quite different from saying that *how* to calibrate all the Other Growth Conditions so as to produce an SG 872 Diamond of a specific quality was common general knowledge at the filing date. There was simply no evidence at all to support this and all we have said about the lack of sufficiency explains why this is untenable.

171 The Judge, however, found that Claim 62 is *not* classically insufficient because the PSA would know *how* to adjust the Other Growth Conditions (*Judgment* at [285]). With respect, we find that she erred. According to the Judge, Dr Bergonzo's evidence was that "the missing details, such as the geometry of the substrate holder, would be within the knowledge of the PSA skilled with working knowledge of the research and development of CVD diamond synthesis" (*Judgment* at [285]).

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[141] RCN at para 49(b).

172 The portion of Dr Bergonzo's evidence the Judge appears to have relied on is found in Dr Bergonzo's report dated 26 June 2019 ("Dr Bergonzo's Reply Report"), which was written in response to Dr Nebel's reports.[142] To understand Dr Bergonzo's evidence in its proper context, we need to summarise the relevant portion of Dr Nebel's 1st Report,[143] to which Dr Bergonzo was responding.

173 Dr Nebel had stated that the PSA would know that the Other Growth Conditions which affect the appropriate concentration of nitrogen include the: "Geometry of reaction chamber, Pressure, Temperature, Gas flow rates, Composition of Source Gas, Microwave Power and quality of substrate used."[144] He noted that Claim 62 "fails to provide accurate process conditions at which [300ppb to 5ppm nitrogen] would result in the intended objective of the method."[145] His views on the Examples bear setting out in full:[146]

> Other than Example 1, only example 9 and 14 provide some variation in conditions of nitrogen in process gas, pressure and methane concentration but *no guidance on missing parameters or further clarity of broadly described parameters are provided.* Further, the patent also does not provide any ***correlation*** or even ***subjective relationship*** on how the level of nitrogen in 'synthesis atmosphere' would change if the process conditions vary from what is mentioned in examples, in order to achieve the same quality of diamond as disclosed in the example. In absence of guidance on specific process parameters and their relationship with level of nitrogen in process gas, the range of 300 ppb to 5 ppm is of little use for the PSA. Since the patent itself defines this range to be 'process dependent', claiming this range without specifying the process parameters for which the range would be valid would be of little use.
>
> [emphasis added in italics and bold italics]

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142 III(A55) ROA 8, 16, 56–58.

143 III(B13) ROA 10; see in particular III(B14) ROA 147–149 (paras 1121–1128).

144 Nebel-1 at para 1222 (III(B14) ROA 147).

145 Nebel-1 at para 1221 (III(B14) ROA 147).

146 Nebel-1 at para 1227 (III(B14) ROA 149).

174 Dr Nebel also mentioned that in the absence of a specific value of microwave power, the PSA would not be able to achieve the plasma power density required. He added that the growth of the diamond is "strongly affected by the geometry of the molybdenum substrate holder used", but SG 872 "doesn't teach anything about the geometry of the substrate holder or the placement of seeds on the substrate holder."[147]

175 Dr Bergonzo's response was that the PSA would know how to achieve "the high plasma density required" and "what substrate holder to use with his reactor".[148] It is immediately clear that Dr Bergonzo only addressed *two* of the Other Growth Conditions and omitted to explain how the PSA would know how to calibrate the remaining variables so as to produce an SG 872 Diamond of a specific quality. Therefore, even taking Dr Bergonzo's evidence in respect of the geometry of the substrate holder, on which the Judge appeared to focus (*Judgement* at [285]), at face value, this is no answer to the difficulty the PSA faces in determining all of the *remaining* Other Growth Conditions.

176 As for Dr Bergonzo's evidence on the appropriate plasma power density, he does *not* claim that the PSA would know how to *calibrate* this parameter depending on the quality of diamond desired. Dr Bergonzo simply testified that the PSA would combine his knowledge of the typical microwave power with the gas pressure used in Example 1 (263 x 10^2 Pa) to "give … the high plasma density required":[149]

> (a) A typical substrate diameter at the time was around 50 mm. Based on the above patent reference this relates to a microwave power around 5 kW.

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147 Nebel-1 at para 1225 (III(B14) ROA 148).

148 Bergonzo-2 at paras 196(c) and 200(a) (III(A55) ROA 57).

149 Bergonzo-2 at para 196 (III(A55) ROA 56–57).

> (b) To apply 5 kW effectively to a 50 mm substrate at the high pressures required by the patent (e.g. 263 x 100 Pa) requires a microwave chamber such as that provided in the SEKI/ASTeX cylindrical reactor, which was the most commonly available commercial reactor at the time, and one which had also spawned many 'home built' replicas.
>
> (c) The combination of the pressure and the power then give us the high plasma density required – no variable is missing

177 But knowing how to achieve a "high plasma density" is not the same as knowing how to *vary* the plasma density to achieve a *specific* diamond in the range of diamonds covered by SG 872's product claims.

178 Dr Bergonzo's first report dated 13 May 2019 is also of no assistance to the respondent. There, Dr Bergonzo asserts that the "***description*** of SG '872 provides ... [a] detailed summary of the substrate conditions used ... includ[ing] sizes, thickness, orientation, surface roughness, plasma etch conditions, duration and temperature, etc. This can be found, for instance, under ***Example 1*** of SG '872. ... I am unable to identify any more points or parameters that needed to be, or should have been, disclosed to a PSA"[150] [emphasis added in bold italics]. However, as we analysed at [152]–[168] above, the specification of SG 872 does *not* provide enabling disclosure across the whole breadth of Claim 62.

179 Read in its proper context, Dr Bergonzo's evidence does not address the heart of Dr Nebel's concern: that "The '872 Patent fails to provide any teaching on these other parameters and their relationship with the claimed properties of CVD diamond."[151] We agree with Dr Nebel. Dr Bergonzo also does not appear to expressly assert that a method to calibrate all the Other Growth Conditions

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150 Dr Bergonzo's 1st Report at para 120 (III(A52) ROA 96).

151 Nebel-1 at para 1266 (III(B14) ROA 161).

was within the PSA's *common general knowledge* at the filing date. In so far as he does, he and the respondent have failed to back this up with evidence to show that this was "generally known and generally *regarded as a good basis for further action* by the bulk of those who are engaged in the particular art" (see [74] above) and we reject any such contention.[152]

180 Therefore, having regard to the language of the claim itself, the relevant context in SG 872 and the expert evidence, we overturn the Judge's finding that Claim 62 is not classically insufficient and hold it to be invalid in so far as the respondent's claim for infringement is concerned.

181 We accept that a claim in a patent is not required to specifically describe "all possible ways in which the invention can be carried out" (*Halsbury's Singapore IP* at para 160.369). The inventor cannot be expected to relieve the PSA from all obligation to take trouble in carrying into effect the description in the specification (*First Currency Choice* at [67]). Rather, what is lacking in Claim 62, and the specification of SG 872, is a teaching of a general principle that enables the PSA to (a) understand the relationship between the Other Growth Conditions and nitrogen concentration; and (b) determine how to calibrate the Other Growth Conditions to grow a diamond of a specific quality.

(E) THE OTHER PROCESS CLAIMS

182 In light of the foregoing, Claims 63 to 71, process claims which refer back to and narrow the process taught in Claim 62, are likewise classically insufficient. For example, Claim 63 monopolises "[a] method according to claim 62, wherein the synthesis atmosphere contains more than 500 ppb nitrogen" while Claim 67 monopolises "[a] method according to any of claims

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152 See also PCS2 at para 1322 (III(G3) ROA 235).

62 to 66, wherein the density of defects is such that surface etch features related to defects is below $10^2/mm^2$."[153] All of these subsequent process claims require an understanding of how to calibrate the Other Growth Conditions in order to grow a diamond of a specific quality, but, like Claim 62, are utterly devoid of such guidance.

Whether the Product Claims are also classically insufficient

183 Since *all* of the process claims in SG 872 (meaning Claims 62 to 71) are classically insufficient, and since it is the respondent's case that producing an SG 872 Diamond was not possible prior to the discovery of the process in Claim 62 (in particular, the Claim 62 Nitrogen Range) (see [39] above), the sufficiency of these product claims is called into question.

184 As a starting point, working a product claim entails *making* the product (see *Regeneron (SC)* at [23]). A product claim's contribution to the art is "the ability of the skilled person to make the product itself ..." (*Regeneron (SC)* at [56(ii)]). The patentee cannot obtain a product monopoly without disclosing how to make the product because if it were otherwise, the public would get nothing of substance in return for the grant of monopoly and the patent bargain described at [57] and [102] would be not be satisfied (see *Regeneron (SC)* at [23]). And, a claim must enable the invention to be performed over its *whole breadth* (see [108]–[109] and [114] above; *Saint-Gobain* at [196]). We also explained at [83]–[93] that each product claim in SG 872 asserts a monopoly over a class of products. Hence, the question is whether the specification of SG 872 sufficiently enables the PSA to produce diamonds across the entire breadth of each product claim in SG 872.

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153 BOM at pp 374–375.

185 Having found that *all* the process claims in SG 872 are classically insufficient, we are satisfied that all the *product* claims are invalid for the same reason. Claims 62 to 71 assert that the process taught therein enables the PSA to produce an SG 872 Diamond.[154] Since these process claims are classically insufficient, the PSA is faced with an undue burden to grow diamonds across the *entire* range of products claimed in each product claim. This is not to say that the sufficiency or, more generally, the validity of a product claim is necessarily tied to that of a related process claim as a matter of law. This happens to be the case on the present facts because SG 872 does not teach an alternative method of producing an SG 872 Diamond besides the one found in Claims 62 to 71 (see also [39] above), and neither is it the respondent's case that there is a method within the PSA's common general knowledge to grow SG 872 Diamonds.

186 We return to our earlier reference to the substantiality threshold in *Regeneron (SC)* (see [112] above). In our view, even if all that is required is enablement *substantially* across the breadth of each product claim, that standard is not met. As we observed above at [154], the specification of SG 872 only teaches the production of *five* variants of an SG 872 Diamond. There are, however, innumerable combinations of values of Other Growth Conditions and nitrogen concentrations to use, and innumerable embodiments of an SG 872 Diamond disclosed in Claim 1 (which we take to be the broadest product claim in SG 872). Enabling five variants of an SG 872 Diamond is not substantial enablement.

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154 BOM at p 374.

Revocation

187 As all claims in SG 872 are invalid for classical insufficiency, we allow the appellant's counterclaim and revoke SG 872 in its entirety under s 80(1)(*c*) of the Patents Act (2005 Rev Ed). Although this is sufficient to dispose of the appeal, we briefly consider one further difficulty.

Whether any or all of the claims in SG 872 are invalid due to uncertainty

Whether Claim 1 is uncertain

188 To recap, low birefringence is quantified in Claim 1ii) as a sample with (a) δ remaining in the SG 872 First Order; and (b) |sin δ| not exceeding 0.9. Low birefringence is quantified in Claim 1iii) as a sample with (a) δ remaining in the SG 872 First Order; and (b) $\Delta n_{[average]}$ not exceeding 1.5 x 10^{-4}. The specification of SG 872 directs the PSA to use a Deltascan (which has been renamed as the Metripol since 2001) or a "similar instrument with similar resolution". The question which arises for our consideration is whether the PSA would know what test he should apply to ascertain whether a particular single crystal CVD diamond satisfies the integer that δ is within the SG 872 First Order.

189 The respondent claims that there are three instruments which are similar to the Metripol – the Polscope, the Millipol and the Rotopol.[155] We reject the respondent's allegation that the Polscope is a similar instrument. According to Dr Geday, though the Polscope was available in 2002 and was considered a direct competitor to the Metripol, it was less precise and hence inferior to the Metripol.[156] The respondent has not shown us any other material which

155 RC at para 177.

156 Transcript, 24 July 2019, pp 8:17–9:6 (III(D4) ROA 13–14).

contradicts Dr Geday's evidence. In so far as the Millipol and the Rotopol are concerned, it is common ground that both these instruments are similar to the Metripol but were developed only by 2009.[157] As such, they could not have formed part of the PSA's common general knowledge at the relevant time and cannot be relied upon as enabling the PSA to test for the parameters in Claims 1ii) and 1iii). In these circumstances, the following analysis will focus only on the Metripol.

190 It is common ground between the parties that the Metripol, on its own, does not give the PSA data to determine whether the δ value of a single crystal CVD diamond material falls within the SG 872 First Order. This has been referred to as the "Metripol Uncertainty Problem". The reason for this is that the Metripol does not calculate δ. The Metripol generates the value of |sin δ|, but each |sin δ| value corresponds to many δ values and only one of these δ values lies within the SG 872 First Order. A graphical representation of this can be found at [35] above. It is for this reason that the appellant submits that Claims 1ii) and 1iii), and SG 872 as a whole, is invalid for insufficiency by ambiguity, or, as we prefer to term it, uncertainty.[158]

191 Against this, the respondent claims that Dr Kaminsky had testified that he "totally disagree[d]" that the Metripol Ambiguity Problem was "insoluble".[159] This is a mischaracterisation of Dr Kaminsky's testimony. The cross-examination of Dr Kaminsky had proceeded on the basis that each "order" is a multiple of 2π, and "first order" was defined as δ not exceeding 2π. This is distinct from the SG 872 First Order which is specifically and more narrowly

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157 Primer at para 158.

158 ACN at para 16.

159 RC at para 178.

defined in terms of δ not exceeding $\frac{\pi}{2}$. However, it was in the former context that Mr Alvin Yeo SC, counsel for the respondent, asked Dr Kaminsky if he thought that it was an "insoluble problem" to determine "which order" δ was in. Dr Kaminsky replied that he "totally disagree[d]" that it was an insoluble problem.[160] Thus, when understood in context, Dr Kaminsky's position, at its highest, is that it is possible to determine whether δ is between 0 and 2π. However, this does not necessarily mean that it is possible to determine whether δ falls within a more narrow range of values between 0 and $\frac{\pi}{2}$ (that is, the SG 872 First Order) (see above at [31]).

192 The respondent further submits that there are four solutions to the Metripol Uncertainty Problem which the PSA would know of. The first solution is to interpret the data obtained from the Metripol using the PSA's knowledge of the nature and characteristics of single crystal CVD diamond material, with reference to Dr Glazer's Gap Theory.[161] If the PSA remained in doubt as to whether δ is within the SG 872 First Order, he could use a second method known as the Cross-Polariser Method. This involves the use of cross-polar microscopy and the Michel-Levy interference colour chart.[162] The third entails the use of a standard compensating plate with white light. The fourth and final solution is to carry out the measurements using the Metripol at two or more wavelengths.[163] The last two solutions will be collectively referred to as the "Glazer 1996 Solutions", as they are found in "An Automatic Optical Imaging System for

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160 Transcript, 24 July 2019, pp 93:21–94:12 (III(D4) ROA 98–99).

161 RC at paras 179–184.

162 RC at paras 185–189.

163 RC at paras 190–193.

Birefringent Media" (1996) 452 Proc R Soc Lond A 2751 ("Glazer 1996"), a scientific paper referred to in SG 872.[164]

193 In turn, the appellant disagrees that these solutions would enable the PSA to determine if δ is within the SG 872 First Order. We note in passing that although the appellant's argument focuses on whether a particular solution is part of the PSA's common general knowledge at the priority date of SG 872 (meaning 21 November 2002),[165] it is not in dispute that there is no material difference in the common general knowledge of the PSA as at the filing date (20 November 2003) and the priority date (21 November 2002).[166]

194 In our judgment, the appellant, by highlighting the Metripol Uncertainty Problem, has adduced sufficient evidence to suggest that the PSA would not have been able to determine if δ is within the SG 872 First Order for a particular single crystal CVD diamond. The evidential burden thus shifts to the respondent to show that the PSA would know of a workable solution to overcome this and would be able to ascertain whether δ is within the SG 872 First Order in so far as single crystal CVD diamonds are concerned. This means that the respondent must show that any of the four solutions set out at [192] above fulfil two cumulative criteria: (a) it is a workable solution for ascertaining whether δ is within the SG 872 First Order where single crystal CVD diamonds are concerned, and (b) it is a solution that would have been known to the PSA either because (i) it is taught in the patent or (ii) it is part of the common general knowledge (*Glaxo Group* at [180]–[181]). The four solutions raised by the respondent do not fulfil either or both of these criteria.

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164 BOM at p 330.

165 See AC at para 160.

166 See AC at p 70.

(1) The Gap Theory

195 We begin with the Gap Theory, which was accepted by the Judge as providing a solution to the Metripol Uncertainty Problem (*Judgment* at [200]–[204]).

196 The respondent, relying on the evidence of Dr Glazer and Dr Newton, submits that the PSA using the Gap Theory would be able to tell from the Metripol measurements whether the sample remained in the SG 872 First Order. According to the respondent and Dr Glazer, the Gap Theory works on the premise that the PSA would know the following (collectively, the "Premises"):[167]

(a) A theoretically perfect diamond with no strain-causing defects is isotropic and would, if measured, show $|\sin \delta|=0$ and $\delta=0$ (the "First Premise").

(b) If the Metripol $|\sin \delta|$ Map of the analysed area of a sample shows regions in which $|\sin \delta|$ is close to 0 without significant spatial variations associated with defects causing strain, these regions correspond to δ being close to 0 (the "Second Premise").

(c) Strain in the material varies continuously, and thus, δ and the $|\sin \delta|$ measurements are continuous with no gaps (the "Third Premise").

197 The respondent submits that with the knowledge of the Premises, the PSA, in respect of an analysed area without significant spatial variations associated with defects causing strain, would know that the analysed area

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[167] RC at para 180; RSA at para 55; Transcript, 22 July 2019, pp 123:23–127:5, 141:3 (III(D3) ROA 128–132, 146); Dr Anthony Michael Glazer's 2nd Report ("Glazer-2") at paras 7, 62 and 75 (III(A43) ROA 16, 28 and 31).

remains in the SG 872 First Order ($\delta \leq \frac{\pi}{2}$) if the |sin δ| values extend upwards from close to zero to a maximum value ($|\sin \delta|_{max}$) that is not close to 1 (meaning that there is a gap between $|\sin \delta|_{max}$ and 1).[168] Dr Glazer explained at the trial that this interpretation is based on the understanding that δ varies continuously. He said that it is not possible for there to be a gap between $|\sin \delta|_{max}$ and 1, and for there to be δ values outside the SG 872 First Order simultaneously. If there are δ values outside the SG 872 First Order, there must have been a *continuous* range of δ values which extends from 0 up to those values beyond the SG 872 First Order, in which case, there would be no gap between $|\sin \delta|_{max}$ and 1.[169] The Gap Theory therefore determines whether δ remains in the SG 872 First Order by looking at whether there is a gap between $|\sin \delta|_{max}$ and 1. If this gap exists, the range of δ values must be within the SG 872 First Order; if this gap does not exist, the range of δ values must have extended beyond the SG 872 First Order.

198 Whether the Gap Theory is sound is a major point of dispute between the parties both at trial below and on appeal. Much of the dispute on this point turned on whether the Gap Theory has been disproved in the light of a small yellow streak in a cross-polarised image of Sample 2. However, it is unnecessary for us to resolve this factual dispute because even if we assume in the respondent's favour that the Gap Theory is sound, the respondent has not proven that the Gap Theory would have been known to the PSA at the relevant time.

199 At the outset, a PSA reading the specification of SG 872 would not know of the Premises or know that he should use the Gap Theory to determine whether

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168 RC at paras 180 and 181.

169 Transcript, 22 July 2019, pp 123:23–127:5, 141:3 (III(D3) ROA 128–132, 146).

δ falls within the SG 872 First Order. At trial, Dr Glazer tried to rely on the following passage to claim that it teaches the PSA to use the Gap Theory:[170]

> …[T]he modulus of the sine of the phase shift, $|\sin \delta|$, as measured by a Deltascan or similar instrument… does not exceed 0.9, and preferably does not exceed 0.6, and more preferably does not exceed 0.4, and more preferably does not exceed 0.3, and more preferably does not exceed 0.2.

We disagree with Dr Glazer. This passage does not even tell the PSA to look out for a gap between $|\sin \delta|_{max}$ and 1, much less the significance of that gap in determining whether δ falls within the SG 872 First Order. Notably, the respondent did not seek to rely on Dr Glazer's evidence in this regard.

200 The Gap Theory, including its Premises, must be part of the common general knowledge at the relevant date in order for it to be attributed to the PSA. In this regard, we agree with the appellant's submission that the respondent has not established that the Gap Theory was part of the PSA's common general knowledge.[171] This evidential gap is fatal to the respondent's case, given that it is the respondent which bears the evidential burden to show that the PSA would know, as part of his common general knowledge, a workable solution to determine if δ is within the SG 872 First Order (see above at [194]).

201 Dr Glazer and Dr Newton gave evidence that the PSA would know how to interpret the Metripol data with reference to the Gap Theory, but neither expert cited any publications, released at or before the relevant date, which referred to the Gap Theory. Proof that scientific publications have described the Gap Theory as a solution to the Metripol Uncertainty Problem does not necessarily demonstrate that the Gap Theory was part of the common general

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170 Transcript, 22 July 2019, pp 149:11–151:5 (III(D3) ROA 154–156); BOM at p 302.

171 AC at paras 160–164; ACN at paras 16(f) and 16(j).

knowledge, but it would, at the very least, have been *prima facie* evidence that it was (see above at [74]). Indeed, while the First Premise can be inferred from what the parties agreed to be the common general knowledge (see above at [24]–[27]), the same cannot be said for the Second and Third Premises. Yet, the respondent, Dr Glazer and Dr Newton did not refer us to any publications which would establish these two premises as part of the common general knowledge.

202 To bolster the Third Premise, the respondent relies on a histogram prepared for each Sample. Each histogram graphically depicts the number of pixels which have a particular |sin δ| value as measured by the Metripol. These histograms were set out in Dr Newton's first report dated 13 May 2019 ("Dr Newton's 1st Report"), wherein he sought to prove that the Samples infringed Claims 1ii) and 1iii).[172] We set out the histogram for Sample 3 for illustration:

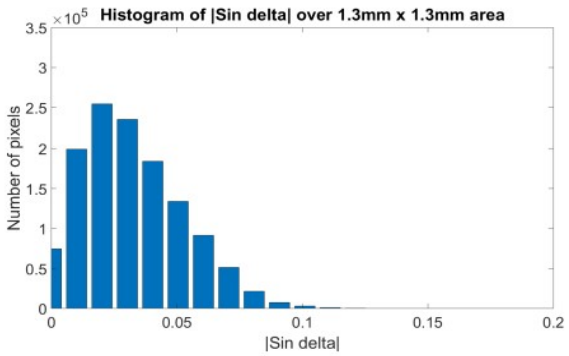

Figure 15: Histogram of |sin δ| over 1.3mm x 1.3mm area for Sample 3

According to the respondent, these histograms demonstrate that the continuity of strain in single crystal CVD diamonds results in |sin δ| measurements which are continuous.[173] We find that these histograms do little to advance the

172 III(A24) ROA 91 (Sample 2), 114 (Sample 3) and 142 (Sample 4).

173 RC at para 182.

respondent's case. These histograms do not show the more crucial point that δ varies continuously with no gaps (see above at [197]).[174] More importantly, neither Dr Glazer nor Dr Newton relied on such a histogram in their expert reports to show that the PSA knew that |sin δ| measurements of a single crystal CVD diamond would vary continuously in value *because* of the continuity of strain in the diamond. After all, these histograms are only prepared in respect of three samples and cannot be representative of a wider trend, or proof that this fact was well accepted by those skilled in the art.

203 The respondent notes that Dr Kaminsky did not challenge Dr Glazer's and Dr Newton's evidence that the PSA would be aware of the Gap Theory and its Premises.[175] In our judgment, however, that alone cannot suffice to establish that the Gap Theory and its Premises were common general knowledge at the relevant time because no supporting material was cited. Dr Glazer's and Dr Newton's evidence, whilst unchallenged, remain bare assertions and do not justify a finding of fact that the Gap Theory and its Premises were common general knowledge.

204 This difficulty is enhanced when we have regard to a point made by the appellant in seeking to undermine the credibility of Dr Glazer's and Dr Newton's assertion that the PSA would know of the Gap Theory and its Premises. The Gap Theory and its Premises were first raised in Dr Glazer's and Dr Newton's second reports, *after* Dr Newton had concluded in the infringement analysis of his 1st Report that each Sample had a range of δ values within the SG 872 First Order. As pointed out by the appellant,[176] Dr Newton

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174 Transcript, 22 July 2019, pp 123:23–127:5, 141:3 (III(D3) ROA 128–132, 146).

175 RC at paras 183–184.

176 AC at para 163.

did *not* use the Gap Theory or any of its Premises in coming to his conclusion on infringement in his 1st Report. For each Sample, Dr Newton observed that "the Metripol images show regions that clearly have a low density of strain-inducing defects",[177] and supports this by simply pointing to a Metripol |sin δ| Map (in greyscale and colour) of the entire Sample which is created by taking overlapping Metripol |sin δ| Maps and stitching them together using a software programme.[178] No further elaboration was given. In respect of each Sample, Dr Newton then proceeded to identify the $|\sin \delta|_{max}$ value of the analysed area, and computed *one* maximum δ value (δ_{max}) from $|\sin \delta|_{max}$. We emphasise the fact that Dr Newton only derived *one* δ_{max} value. This is curious, since it is common ground that as a matter of arithmetic, each |sin δ| value corresponds to many δ values (see above at [35]). Dr Newton's 1st Report did not explain why he was able to derive only *one* δ_{max} value from the $|\sin \delta|_{max}$ value. What is even more notable is that the δ_{max} value Dr Newton arrived at happened to be within the SG 872 First Order. From this, Dr Newton concluded that the range of δ values is confined within the SG 872 First Order. At no point in his 1st Report did Dr Newton expressly rely on the Gap Theory, or make any statement which shows that he deduced that the δ_{max} value must have been within the SG 872 First Order because there is a gap between $|\sin \delta|_{max}$ and 1. If the PSA would have known of and deployed the Gap Theory (because the Gap Theory *was* part of the common general knowledge at the relevant time), one would have expected Dr Newton to use it in his infringement analysis to prove that the δ_{max} value of each Sample must have been within the SG 872 First Order. This was not done. Instead, the Gap Theory was only raised in Dr Glazer's and Dr Newton's second

177 III(A24) ROA 91 (Sample 2), 114 (Sample 3) and 142 (Sample 4).

178 III(A30) 95 (NL 625-03 (Sample 2)); III(A13) ROA 204 (NL 702 (Sample 3)); III(A32) ROA 59–60 (NL 719-06 (Sample 4)).

expert reports, after the appellant raised the objection that the PSA would not know how to determine when δ was within the SG 872 First Order.

205 The foregoing is further reinforced by the fact that Dr Glazer, the main proponent of the Gap Theory,[179] simply stated in his first expert report that he agreed with Dr Newton's infringement analysis without seeking to plug the gap in Dr Newton's infringement analysis by referring the court to the Gap Theory.[180]

206 For these reasons, in our judgment, the respondent cannot rely on the Gap Theory to resolve the Metripol Uncertainty Problem. The Judge therefore erred when she accepted the Gap Theory without first considering whether it was part of the common general knowledge at the relevant time.

207 There is a further issue with the Gap Theory, even if we were to assume that it was part of the common general knowledge. On the respondent's own case, the Gap Theory only works on the condition that the sample will show regions in which |sin δ| is close to zero without significant spatial variations associated with defects causing strain. The appellant points out that not all single crystal CVD diamond samples will have this characteristic.[181] The respondent derides the appellant for not adducing expert evidence to make good the assertion that not all single crystal CVD diamond samples will fulfil that condition,[182] but in our judgment, it is the respondent who has the evidential burden of showing that single crystal CVD diamond samples will generally fulfil that condition. As noted earlier at [194] above, the evidential burden has

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179 Newton-2 at para 41 (III(A56) ROA 48).

180 Dr Glazer's 1st Report ("Glazer-1") at paras 54–55 (III(A21) ROA 24–25).

181 AC at para 157.

182 RC at para 182.

shifted to the respondent to show that there exists a workable test to determine whether δ falls within the SG 872 First Order. The respondent points to the Gap Theory, which works only when the sample shows regions in which |sin δ| is close to zero without significant spatial variations associated with defects causing strain.[183] To discharge its evidential burden of showing a workable test, the respondent must *at least* show that most, if not all, single crystal CVD diamond samples would satisfy the condition upon which the Gap Theory works. In our judgment, the respondent has not done so. Accordingly, the respondent has not proven that the Gap Theory is a workable test such that a PSA, analysing any single crystal CVD diamond sample in his possession, would be able tell if it fulfils the integer relating to the SG 872 First Order.

(2) Cross-Polariser Method

208 The Cross-Polariser Method, which involves the use of cross-polar microscopy and the Michel-Levy interference colour chart, was common general knowledge at the relevant time. Cross-polar microscopy works by shining a beam of white light on two polarisers, which are placed perpendicular to one another. If a birefringent material is placed between the first polariser and the second polariser, the polarised light passing through the material is slowed down (or retarded). Depending on the extent of retardation, different wavelengths constituting white light (400nm to 700nm) may interfere and display colour when the resulting beam is imaged on a plane. The cross-polarised image of an isotropic crystal (one with no birefringence) will be completely dark, but the cross-polarised image of a highly anisotropic crystal (one with high birefringence) will be colourful. The colours in the image are

[183] See RC at para 180; RSA at para 55; Glazer-2 at paras 62 and 75 (III(A43) ROA 28 and 31).

then compared against the Michel-Levy interference colour chart to ascertain the birefringence of the material.[184]

209 Figure 16 depicts how δ values (within the range of 0 to 2π) can be derived upon locating the colours in the cross-polarised image in the Michel-Levy interference colour chart:[185]

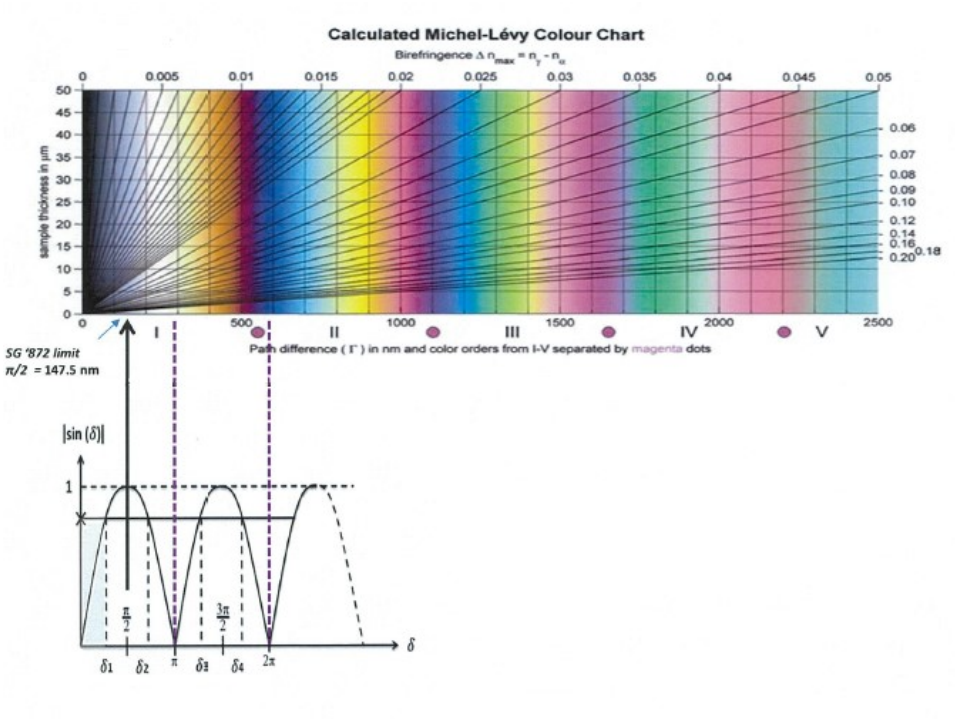

Figure 16: Diagram depicting how the values of δ are derived from the Michel-Levy interference colour chart

Where a particular region of the cross-polarised image contains dark magenta, δ is close to 2π. If a particular region is completely dark, δ is at or extremely close to 0.[186]

184 Primer at paras 43–46.

185 IV(B) ROA 33.

186 See Primer at para 47; III ACB 152 (para 183(5)).

210 According to the respondent, if the cross-polarised image of the diamond sample only shows black, white or grey contrasts, it indicates that δ is within the SG 872 First Order.[187]

211 We are unable to accept the Cross-Polariser Method as a workable test which sufficiently helps a PSA determine whether δ is within the SG 872 First Order.

212 First, the Cross-Polariser Method is an inherently imprecise method as it requires a qualitative judgment of the shade of colour perceived in the cross-polarised image. Dr Nebel accepted that if a particular region shows up as black in the cross-polarised image, a PSA will know that the region is strain-free or near perfect.[188] Accordingly, the PSA will know that δ is within the SG 872 First Order for that particular region. However, Dr Nebel pointed out that the presence of any other colour indicates that a particular region has some birefringence, but the interpretation of that colour will be "subjective".[189] This is in line with the respondent's own acknowledgement that the Cross-Polariser Method is only a "qualitative assessment" that gives the PSA an *approximation* of whether δ is within the SG 872 First Order.[190]

213 Second, the parties agree that it is common general knowledge that even if the cross-polarised image shows black, white and grey contrasts, and an absence of other colours, this is not a conclusive indication that δ is less than or

187 RC at paras 185 and 187; RCN at para 53(b).

188 III ACB 152 (para 183(5)).

189 III ACB 152 (para 183(3)).

190 RC at paras 188 and 201–202; RSA at para 56.

equal to $\frac{\pi}{2}$, even though it can indicate that δ is less than or equal to 2π.[191] In particular, it is common general knowledge that grey contrasts may be a result of δ *exceeding* $\frac{\pi}{2}$.[192] This is illustrated in Figure 16 above at [209].

214 The respondent points out that Dr Newton, in the infringement analysis of his 1st Report, had cross-checked the Metripol data against the Cross-Polariser Method to confirm that the range of δ values of the Samples were within the SG 872 First Order.[193] However, a closer examination of Dr Newton's analysis suggests that the Cross-Polariser Method had not conclusively indicated that the range of δ values of the Samples were in fact within the SG 872 First Order. In his 1st Report, Dr Newton observed that cross-polarised images of the Samples "show only black/white/grey contrast" with no other colour. On this basis, he ruled out δ values *near* π and concluded that this was "further evidence" that the range of δ values was within the SG 872 First Order (δ does not exceed $\frac{\pi}{2}$) for 100% of the analysed area.[194] With respect, it is unclear how Dr Newton can reach this conclusion given that it is common general knowledge that the presence of grey contrasts may be because δ exceeds $\frac{\pi}{2}$,[195] and the ruling out of δ values *near* π does not indicate that δ *must be* less than $\frac{\pi}{2}$. Dr Newton added that the absence of other colour "is consistent with δ not exceeding $\frac{\pi}{2}$". This is true, but the absence of other colour is also consistent with

191 Primer at para 155.

192 Primer at para 155.

193 RC at para 187.

194 III(A24) ROA 95 (Sample 2), 118 (Sample 3) and 142 (Sample 4).

195 Primer at para 155.

δ exceeding $\frac{\pi}{2}$. As such, the cross-polarised images do not *conclusively* show that δ is less than or equal to $\frac{\pi}{2}$.

215 Thus, even though the Cross-Polariser Method was part of the common general knowledge at the relevant time, it is generally an imprecise and inconclusive method. Admittedly, the Cross-Polariser Method can conclusively show that δ is at or extremely close to 0 if the particular region under analysis *only* shows the colour black, in which case the region is strain-free or near perfect and δ must be within the SG 872 First Order (δ does not exceed $\frac{\pi}{2}$). However, the reliability of the Cross-Polariser Method in this narrow situation cannot save it from being a generally unreliable solution.

216 The respondent is aware of the drawbacks of the Cross-Polariser Method, and has sought to present the Cross-Polariser Method as a "confirmatory step" which can be used to cross-check the Metripol data.[196] It suggests that the PSA can use the Cross-Polariser Method to ascertain whether δ is *approximately* within the SG 872 First Order, before going on to determine from the quantitative Metripol data whether δ is actually within the SG 872 First Order.[197] We do not see how this helps a PSA conclusively determine that δ is within the SG 872 First Order. The Metripol data itself does not tell the PSA whether δ is within the SG 872 First Order (see above at [190]), and it is a misnomer to term the Cross-Polariser Method as a confirmatory step when any "confirmation" is not conclusive. In so far as the respondent is saying that the Cross-Polariser Method, coupled with an analysis of the Metripol data using the Gap Theory, can enable the PSA to determine whether δ is within the SG 872

196 RC at para 187.

197 RC at para 188.

First Order, this is impermissible since we have held that the Gap Theory has not been shown to be a part of the common general knowledge at the relevant time (see above at [200]–[206]).

(3) Glazer 1996 Solutions

217 The patent specification of SG 872 directs the PSA to Glazer 1996 for "[a]n explanation of how the Deltascan works":[198]

> The Deltascan (Oxford Cryosystems) gives information on how the refractive index at a given wavelength depends on polarization direction in the plane perpendicular to the viewing direction. An explanation of how the Deltascan works is given by A. M. Glazer et al. in Proc. R. Soc. Lond. A (1996) 452, 2751-2765.

As mentioned, the Deltascan was later renamed as the Metripol.[199] The only paragraph in Glazer 1996 which sets out the Glazer 1996 Solutions reads:[200]

> Finally, it should be realized that, because it is $|\sin \delta|$ that is obtained at any point in the image, it is not possible to know how many periods (known as the *order*) of the sine function have been passed through, unless other information is supplied. The easiest way to solve this is to use a standard compensating plate with white light. A quick observation of this type will then suffice to determine the order within which the retardation value lies. Carrying out the measurements at two or more wavelengths can also be used to help in determining the order.
>
> [emphasis in original]

218 Both parties did not submit on whether an external document referred to in a patent specification is incorporated into the patent specification and hence relevant to the assessment of sufficiency. However, even if we assume in the

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198 BOM at p 330; Transcript, 22 July 2019, pp 172:8–173:12 (III(D3) ROA 177–178).

199 Primer at para 146.

200 V(A22) ROA 68.

respondent's favour that Glazer 1996 can be treated as a part of the patent specification and that the PSA knows of the Glazer 1996 Solutions as a result, the respondent has not shown that the Glazer 1996 Solutions are in fact workable tests for the purpose of determining whether a particular single crystal CVD diamond material has a δ value within the SG 872 First Order.

219 First, Glazer 1996 itself does not indicate that the Glazer 1996 Solutions apply to single crystal CVD diamonds.

220 Glazer 1996 did not expressly or implicitly contemplate the applicability of the Glazer 1996 Solutions to single crystal CVD diamonds. By way of background, Glazer 1996 is a scientific paper which sought to introduce the Metripol (which was at that time a new optical microscope-based imaging system) and demonstrate that it is "a potentially important research tool for the study of optical anisotropy in many disciplines" and "any situation where birefringence is of interest".[201] It set out a general discussion of how the Metripol works, its usefulness as well as its limitations, including its inability to tell how many "periods" of the sine function have been passed through in the absence of other information supplied. It was in this general context that Glazer 1996 proposed the Glazer 1996 Solutions. Glazer 1996 was not concerned with the specific application of this system to single crystal CVD diamonds, and in fact made no mention of this particular class of diamonds. Although Glazer 1996 briefly considered the application of the Metripol to a synthetic diamond sample for the purpose of illustrating the versatility and use of the Metripol,[202] Dr Glazer, a co-author of Glazer 1996, clarified in his second expert report that the synthetic diamond sample under consideration was a *HPHT* synthetic

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201 III(A43) ROA 176.

202 III(A43) ROA 171–173.

diamond.[203] He also testified that Glazer 1996 was not published with single crystal CVD diamonds in mind.[204]

221 Second, Glazer 1996 proposed the Glazer 1996 Solutions as methods to ascertain "how many periods (known as the *order*) of the sine function have been passed through" [emphasis in original],[205] but it is unclear whether the word "order" refers to multiples of $\frac{\pi}{2}$. The respondent's own expert, Dr Newton, points out that the word "order" can have different definitions depending on the specific optics field in question.[206] The word "order" may, in the alternative, refer to multiples of 2π with the "first order" covering a range of values where δ does not exceed 2π ,[207] in which case the determination of how many "orders" of sine function have been passed through using the Glazer 1996 Solutions would not help the PSA conclusively ascertain if δ falls within the more limited range covered by the SG 872 First Order (δ does not exceed $\frac{\pi}{2}$).

222 And, apart from Glazer 1996, there is no indication from the body of expert evidence that the Glazer 1996 Solutions can determine whether the δ value of a single crystal CVD diamond is within the SG 872 First Order. The respondent's experts did not expressly mention that the Glazer 1996 Solutions can achieve this.[208] Neither did they apply the Glazer 1996 Solutions when seeking to prove that the Samples infringed Claim 1.[209]

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203 Glazer-2 at para 6(g) (III(A43) ROA 15–16).

204 Transcript, 22 July 2019, pp 130:19–24, 135:6–11 (III(D3) ROA 135 and 140).

205 V(A22) ROA 68.

206 Newton-2 at para 32 (III(A56) ROA 44); Primer at para 48.

207 Primer at para 154.

208 Transcript, 22 July 2019, p 140:5–18 (III(D3) ROA 145).

209 Newton-1 at pp 84–88, 107–111, 133–138 (III(A24) ROA 91–95, 114–118, 140–145).

223 In particular, notwithstanding that Dr Glazer was a co-author of Glazer 1996, Dr Glazer's own expert reports did not rely on the Glazer 1996 Solutions to solve the Metripol Uncertainty Problem, even though he was aware, by the time of his second expert report, that the Metripol Uncertainty Problem was the subject of contention between the parties.[210] Dr Glazer's second expert report only contained a vague comment that "the PSA could look to Glazer 1996 for the details of the optical path".[211] When asked during cross-examination why he did not mention that the Glazer 1996 Solutions could solve the Metripol Uncertainty Problem in his expert reports, Dr Glazer did not give a satisfactory response:[212]

> Q. If you believed [the Glazer 1996 Solutions] were solutions and ready solutions, at that, how is it you don't say that in any of your reports?
>
> A. Because it's nothing to do with this particular case.
>
> Q. What do you mean it's nothing to do with this particular case? It's got everything to do with it because -- can you let me finish, please. We are concerned with the orders and there you were suggesting the easiest way to solve it is by doing this or that.
>
> Now, if that is a valid solution, then that would have been the easiest thing for you to have said in either your first or second expert report, but you didn't.
>
> A. I was asked to look at the patents and I am commenting on the words of the patent and what that means, and if the patent didn't raise these points, there's no reason why I should raise these points.

Dr Glazer's response is at odds with his first expert report, which stated that he was requested to opine on the use of the Metripol as a method of measurement

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210 Transcript, 22 July 2019, pp 133:12–134:5, 145:5–18 (III(D3) ROA 138–139, 150).

211 Glazer-2 at para 40 (III(A43) ROA 23).

212 Transcript, 22 July 2019, pp 132:10–133:4 (III(D3) ROA 137–138).

for birefringence as set out in Claims 1ii) and iii) of SG 872.[213] The scope of his instructions clearly covered the limitations of the Metripol in ascertaining whether δ is within the SG 872 First Order and solutions to overcome them. Dr Glazer's response also does not sit well with his second expert report, which stated that he was requested to respond to Dr Kaminsky's first expert report,[214] which, amongst other matters, highlighted the Metripol Uncertainty Problem. It is troubling that Dr Glazer did not expressly point to or elaborate on the use of the Glazer 1996 Solutions, notwithstanding that he was a co-author of Glazer 1996 and it was well within the scope of his instructions to raise these solutions.

224 We further note that Dr Glazer testified in re-examination that the use of a standard compensating plate with white light is a "standard way of doing things" which "goes back to the 19th century",[215] but he does not go so far as to say this is a "standard" means of ascertaining whether δ in single crystal CVD diamonds is less than or equal to $\frac{\pi}{2}$.

225 In fact, a comment made by Dr Glazer at trial raises doubts as to the feasibility of using the Glazer 1996 Solutions on single crystal CVD diamonds to ascertain if δ is less than or equal to $\frac{\pi}{2}$:[216]

> Q. You would have wondered why Dr Kaminsky raised that as a problem when, according to [Glazer 1996] that was prepared, what, 23-24 years ago, there was a ready solution?
>
> A. The ready solutions are varied and *to apply some of these solutions to this particular case can be rather difficult*, actually. But it depends. …

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213 Glazer-1 at para 12 (III(A21) ROA 13).

214 Glazer-2 at para 2 (III(A43) ROA 13).

215 Transcript, 22 July 2019, pp 173:3–174:14 (III(D3) ROA 178–179).

216 Transcript, 22 July 2019, p 134:6–12 (III(D3) ROA 139).

226 The appellant, relying on Dr Kaminsky's evidence, argues that the Glazer 1996 Solutions cannot determine if δ is less than or equal to $\frac{\pi}{2}$ in highly heterogeneous diamond samples.[217] The respondent in turn submits that this limitation does not apply to single crystal CVD diamonds, which are homogeneous along the light path. In support of this, the respondent points out that the Judge had accepted Dr Glazer's evidence that birefringence in single crystal CVD diamond mainly results from strain associated with dislocations grown into the material with a line direction that is close to parallel to the growth direction and the strain fields tend to show little variation through the depth of a sample (see *Judgment* at [207]–[210]).[218] We see no reason to disagree with the Judge's acceptance of Dr Glazer's evidence in so far as this specific factual point is concerned. However, even if we accept that the Judge's findings meant that the limitation identified by Dr Kaminsky is inapplicable, it does not go towards discharging the respondent's evidential burden of proving that the Glazer 1996 Solutions could be used on single crystal CVD diamonds.[219] The inapplicability of one possible limitation does not necessarily mean that the Glazer 1996 Solutions can be used on single crystal CVD diamonds. Apart from submitting that the appellant has no scientific basis for its assertion that the Glazer 1996 Solutions are inapplicable to single crystal CVD diamonds, the respondent has not drawn our attention to evidence which positively proves that they are in fact applicable.

227 Given the dearth of evidence establishing that the Glazer 1996 Solutions can be used to determine whether δ is within the SG 872 First Order (δ does not

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217 AC at para 154.

218 RC at paras 191–192; RS at para 57; see also Glazer-2 at para 63 (III(A43) ROA 28).

219 Dr Werner Kaminsky's 1st Report ("Kaminsky-1") at para 112 (III(B45) ROA 45).

exceed $\frac{\pi}{2}$) for single crystal CVD diamonds, the respondent cannot rely on the Glazer 1996 Solutions to stave off an insufficiency attack.

(4) Sub-conclusion: Claim 1 is uncertain

228 For these reasons, we find that the PSA trying to perform the claimed invention would not know which test to apply to ascertain whether the δ value of a particular single crystal CVD diamond material remained within the SG 872 First Order. Although this uncertainty only affects one out of two *integers* in limbs ii) and iii) of Claim 1 respectively, the result is that the PSA would not be able to determine whether a particular single crystal CVD diamond material satisfies either limb ii) or limb iii). This bears some similarity to the facts of *Sandvik Intellectual Property AB v Kennametal UK Ltd and another* [2011] EWHC 3311 (Pat), where the uncertainty affecting one out of five integers of the claim in that case likewise caused the entire claim to be held insufficient (at [83] and [162]–[165]).

229 It follows from this that the PSA is unable to perform the invention across the full breadth of the monopoly in Claim 1. As we have found at [83] above, the monopoly asserted in Claim 1 covers a range of single crystal CVD diamond materials, each with a different combination of the physical properties defined in the various limbs of Claim 1. This necessarily includes single crystal CVD diamond materials which satisfy either limb ii) or limb iii), or both. Since the PSA would not know if a particular single crystal CVD diamond material has satisfied limb ii) or limb iii), the PSA would not be able to make a portion of the range of single crystal CVD diamond materials that Claim 1 seeks to monopolise. We therefore find that Claim 1 is invalid for insufficiency.

230 For completeness, we mention two other matters. First, we note that the non-enablement of two out of the eight limbs in Claim 1 does not result in insufficiency of a *de minimis* nature, such that it can nonetheless be said that substantially all products within the scope of Claim 1 have been enabled.

231 Second, we recognise that our finding that the PSA could not determine whether limb ii) or limb iii) has been satisfied raises the question as to how the Judge was able to conclude that all the Samples satisfied both limbs and hence infringed Claim 1 of SG 872. In our judgment, the Judge erred in coming to this conclusion.

232 In respect of Sample 2, the Judge reached her finding of infringement on the basis that the Gap Theory was *capable* of addressing the Metripol Uncertainty Problem (*Judgment* at [431]–[432] and [202]–[204]). With respect, the Judge's analysis on infringement overlooks the issue of whether the Gap Theory was *in fact used* to *prove* that the δ value of Sample 2 was within the SG 872 First Order. Once that is considered, it is apparent from the description of Dr Newton's infringement analysis (see above at [204]) that the Gap Theory was not relied upon. In fact, the Gap Theory as described by Dr Newton and Dr Glazer works on the condition that the sample must show regions in which |sin δ| is close to zero without significant spatial variations associated with defects causing strain, but neither expert expressly stated that Sample 2 fulfilled this condition. Dr Newton stated in his 1st Report that "[t]he Metripol images show regions that clearly have a low density of strain-inducing defects",[220] but it is unclear if this satisfies the condition for the applicability of the Gap Theory. Further, the Judge did not evaluate the reasoning behind Dr Newton's conclusion that the δ value of Sample 2 was within the SG 872 First Order. As

[220] III(A24) ROA 91 (Sample 2), 114 (Sample 3) and 142 (Sample 4).

we have indicated at [204] above, in our judgment, Dr Newton did not give a clear and satisfactory explanation of how he reached this conclusion. We therefore overturn the Judge's finding that Sample 2 infringed Claim 1.

233 Apart from Sample 2, the Judge also found that Samples 3 and 4 infringed Claim 1 of SG 872 on the basis that they satisfied limbs ii) and iii) of Claim 1 (*Judgment* at [435]–[443]). With respect, the Judge arrived at this conclusion without considering whether the δ values of Samples 3 and 4 were within the SG 872 First Order. As with Sample 2, Dr Newton's analysis on infringement did not rely on the Gap Theory, nor did it set out a satisfactory chain of reasoning proving that the δ value of Samples 3 and 4 were within the SG 872 First Order. Accordingly, we overturn the Judge's findings that Samples 3 and 4 infringed Claim 1.

Whether the other claims in SG 872 are also uncertain

234 The appellant, both here and below, argued that if Claim 1 is found to be insufficient due to the Metripol Uncertainty Problem, SG 872 as a whole should be found invalid for insufficiency.[221]

235 We agree with the appellant. The failure to enable part of the monopoly in Claim 1 resulted in the same in respect of all other claims in SG 872. This is because all other claims, be they product or process claims, have defined the scope of their monopoly by reference to Claim 1. We elaborate.

236 As we have noted at [87] above, each subsequent product claim in SG 872 relies on Claim 1 to demarcate the scope of its asserted monopoly. Each subsequent product claim covers any diamond within the class of products in

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[221] IIIG(5) ROA 122 (para 308); AC at paras 143 and 208; ACN at p 16.

Claim 1, which *also* fulfils the additional parameter embodied in the subsequent claim. This will include diamonds which possess the characteristics listed in limbs ii) and iii) of Claim 1. However, the making of these diamond materials is not enabled because the PSA cannot tell when limbs ii) and iii) of Claim 1 are satisfied. Hence, each subsequent product claim is not enabled across its full scope.

237 In respect of the process claims in SG 872, Claim 62 defines the claimed process as one which would produce a single crystal CVD diamond material meeting the requirements of any one of the product claims, including Claim 1. In other words, Claim 62 monopolises a process which produces a range of single crystal CVD diamond materials, including those which possess either or both characteristics in limbs ii) and iii) of Claim 1. Part of this monopoly is not enabled given that the PSA cannot tell when limbs ii) and iii) of Claim 1 are satisfied. The same issue arises in respect of each of the other process claims, which defines its monopoly by reference to Claim 62 such that it also covers a process which produces a range of single crystal CVD diamond material satisfying any one of the product claims.

238 For completeness, we mention in passing that even if all that is required for the sufficiency requirement is for there to be enablement of *substantially* all the subject matter covered by a claim, this threshold is not met in respect of the subsequent product claims and process claims as the non-enablement in each of these claims is not *de minimis*.

Revocation

239 As each claim in SG 872 has not been enabled across the full scope of its monopoly due to the uncertainty affecting limbs ii) and iii) of Claim 1, this

is another ground for allowing the appellant's counterclaim and revoking SG 872 in its entirety under s 80(1)(*c*) of the Patents Act (2005 Rev Ed).

240 Before concluding, we should add that it is unnecessary for us to rule on the correctness of the observation in *Sunseap Group Pte Ltd v Sun Electric Pte Ltd* [2019] 1 SLR 645 ("*Sunseap*") that a patent should be revoked if "all the independent claims in a patent have found to be invalid" because "it follows that the dependant claims must also fall" (at [70]). While the appellant appears to rely on this portion of *Sunseap*,[222] the outcome of this appeal does not turn on its application. We leave further consideration of this observation in *Sunseap* to an appropriate future case.

Conclusion

241 In light of the foregoing, we allow the appeal and set aside the Judge's orders at [45] above. We order the revocation of SG 872. CA 96, which is the appellant's appeal against the Judge's Costs Decision, will, unless we order otherwise, be decided on paper. The parties are to file and exchange written submissions limited to 15 pages in connection with CA 96, within 3 weeks of the date of this judgment, unless they are able to come to an agreement as to its disposal. Similarly, unless the parties come to an agreement, they are to file and exchange written submission limited to 10 pages within 3 weeks of the date of this judgment on the appropriate costs orders we should make in this appeal.

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222 DCS2 at para 283 (ASCB 30), cited in AR at para 76.

Sundaresh Menon
Chief Justice

Judith Prakash
Justice of the Court of Appeal

Steven Chong
Justice of the Court of Appeal

Davinder Singh SC, Srruthi Ilankathir and Hanspreet Singh (Davinder Singh Chambers LLC) (instructed), Tony Yeo Soo Mong, Meryl Koh Junning, Javier Yeo, Loo Fang Hui, Justin Lai Wen-Jin and Derrick Ng (Drew & Napier LLC) for the appellant;
Alvin Yeo SC, Daniel Chan, Daryl Kwok and Yu Zhengyi Victoria (WongPartnership LLP) (instructed), Jason Chan, Melvin Pang and Ong Eu Jin (Amica Law LLC) for the respondent.
