Module B. Colour from the Cosmos

Lesson 9 - Diamond Mineralogy and Gemology

What are Common Treatments for Diamond?

Gemstones have been treated since antiquity in order to improve their shine, polish, aesthetics, colour and ultimately their value. The world of diamond treatments and imitations is vast and many diamonds are treated to improve their clarity and/or modify their colour. Because of the high quality of new diamond treatments it is a continual challenge for gemologists to keep up with new techniques and the fingerprints they leave. Overton and Shigley (2008) published an article titled "History of Diamond Treatments", which is summarized in the text below.

Diamond-specific treatments are believed to have originated in India well before the 2nd century BCE. These treatments were simple and likely consisted of coatings and dyes applied directly to the surface of the stone in order to neutralize an undesirable body colour (e.g., yellow/brown) or enhance a desirable one (e.g., blue). Archaeological evidence also indicates the use of foil backings in Roman rings to give the stone an apparent colour. Modern diamond treatment techniques, however, did not really take off until the 1950’s.

The Deepdene diamond (currently 104.53 ct), which was irradiated and heated in 1955 to intensify its yellow hue, is perhaps the most famous treated-color diamond in the world. Figure from Overton and Shigley (2008).

Modern diamond colour-altering techniques include HPHT annealing (High pressure, High temperature), LPHT annealing (Low pressure, High temperature) and Irradiation, with HPHT annealing being the most important and prominently used process.

Irradiation techniques create vacancies within the atomic lattice of diamond, which generate colour centers that can absorb light in the visible and near infrared portions of the electromagnetic spectrum. These treatments of diamonds were first employed around the turn of the 20th century and the process generally involved exposure of stones to the element radium, which imparted a blueish-green colouration into the stone. This would typically take several months of exposure to achieve and the colour would be limited only to a very thin outer layer of the stone (along with residual radioactivity in the diamond that could last for hundreds of years). With the advent of neutron radiation, the defects (and therefore colour) were able to be imparted throughout the entire stone and leave no detectable radioactivity. Green-coloured diamonds can also be produced naturally if the stones are situated in proximity to certain minerals which emit natural radiation.

HPHT annealing is by far the most common colour treatment for diamonds. By employing this technique, technicians are able to increase the temperature of a diamond while maintaining a very high pressure, andpreventing graphitization (conversion of diamond to graphite) of the stone. This has profound effects on the crystal structure with the ability to alter the combination states of nitrogen impurities (changing from Type Ia to Ib and vice versa) and “heal” lattice vacancies. Depending on the starting type of diamond (e.g., Type I, Type IIa etc.) and the exact temperatures and pressures used, a wide variety of colours could be produced. The most common result of this method is the removal of a brown body colour; and removing or enhancing an existing yellow colour. Other colours such as blue, green, pink and yellow can be produced indirectly after the dominant brown colour is removed and other colour centres are no longer obscured.

These examples illustrate some of the fancy colors that can be produced by HPHT treatment of type Ia (left), type IIa (center), and type IIb (right) diamonds. Figure from Overton and Shigley (2008).

LPHT annealing is a similar process to HPHT except that graphitization of the diamond is encouraged at low pressures. This is often the procedure chosen for highly-flawed stones with numerous inclusions or fractures which are considered unsightly and thus, not very valuable. By increasing the temperature at relatively low pressures, the crystal structure of diamond starts to change to graphite along fracture surfaces. This typically produces an overall black/dark appearance to the stone, hiding the internal imperfections.

Combinations of all three colour treatments are possible with HPHT and irradiation being the most commonpairing. This gives researchers and technicians the ability to produce virtually the entire colour spectrum of diamond depending on the starting stone type and existing colour centres.

A broad array of colors are currently achievable by exposure to radiation and high temperatures+pressures. All of these diamond (0.12–1.38 ct) were color treated by irradiation and— except for the black, blue, and green stones—subsequent heat treatment. Figure from Overton and Shigley (2008).

This figure shows a full range of colours that can be produced in diamonds through a range of diamond treatments. Starting stones (in the center) can be clean or 'dirty' depending on the subsequent treatment(s) and the hopeful outcome. HPHT = High Pressure High Temperature, LPHT = Low Pressure High Temperature. Figure by C. Breeding in Overton and Shigley (2008).

Other treatments are often applied to diamonds (and other gems) that are not aimed towards colour, but are used to treat the stone’s clarity. Three such processes are glass-filling, laser-drilling and acid boiling. Glass-filling is used to fill in surface-reaching fractures and flaws which greatly improves the overall clarity of the stone. The glass used needs to be of an appropriate refractive index in order to reduce the visibility of a fracture within diamond, which has a refractive index of 2.435. In modern treatments, lead-bismuthate glass is typically used which has a refractive index greater than 2 depending on its composition.  Laser-drilling, as the name indicates, involves using a very high powered laser to drill into the diamond to reach inclusions that are otherwise sealed from the surface of the stone. Once an inclusion is reached, the diamond is put in a boiling acid bath which either bleaches or dissolves out the inclusion. The resulting pit and drill hole are then filled in with glass. These three techniques are commonly used in combination with each other.

Introduction of a glass filler into this 0.30 ct diamond's cleavage cracks produced a dramatic change in apparent clarity (before filling, left; after filling, right). Figure from Overton and Shigley (2008).

The laser drill holes in these diamonds serve as a conduit from the diamond's surface to mineral inclusions, which have been lightened or removed by acid boiling. Magnified 10X. Figure from Overton and Shigley (2008).

Although the main objective of treating gemstones is to hide or remove imperfections or undesirable features, it is important for merchants to list all the treatments that have been applied. Failure to do so could deceive buyers and result in damaging the stone if another treatment is applied (e.g. HPHT on a diamond with glass fillings).

**Optional resource:**

[History of Diamond Treatments](https://connect.ubc.ca/bbcswebdav/pid-2559887-dt-content-rid-10494225_1/courses/SIS.UBC.EOSC.118.99C.2014WC.44220/Course_Files/moduleB/lesson09/download/Overton-Shigley1008.pdf)  
Overton. T.W. and Shigley, J.E. (2008)  
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