***Abstract*—**

I. Introduction

The scanning electron microscope (SEM) is a type of microscope that produces images using signals generated from the interaction between electrons and the surface under observation. Higher resolution can be achieved compared to the traditional optical microscope, since electrons have much lower wavelength than light. An SEM can have resolution lower than one nanometre, whereas that of an optical microscope is often limited to a few hundred nanometres. This has benefited a variety of fields. For example, scientists have been using the SEM to analyse the doping density in semiconductors [1] and to view changes in bacterial cells [2].

Fig. 1 shows the basic construction of an SEM. The electron gun generates an electron beam, which is transformed into an electron probe after passing through the condenser lens and objective lens. It is scanned across the specimen under the effect of the scanning coil. As a result of the interaction between the incident electrons and the specimen, some electrons are emitted from the specimen. These are called secondary electrons and are collected by the detector, which generates signals whose magnitude depend on the strength of the secondary electrons. The display unit produces one frame of image after each complete scan of the specimen.

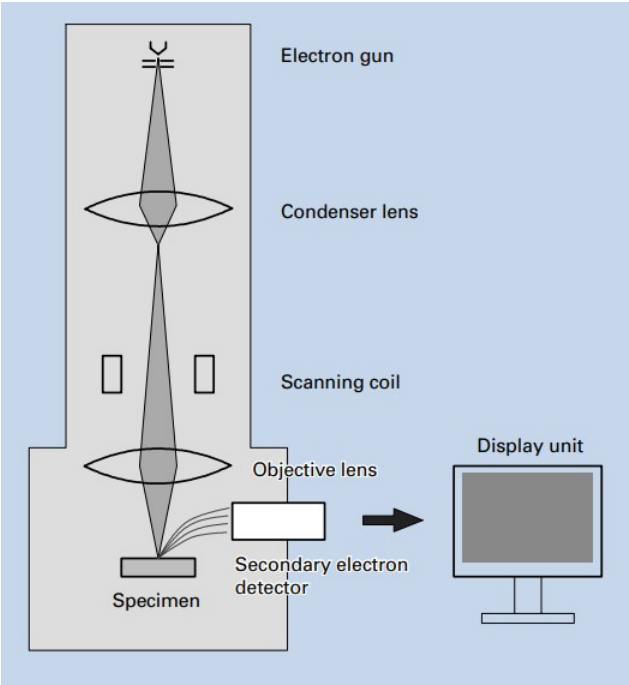

Fig. 1: Basic construction of an SEM [3].

Digital image analysis methods have been widely used in the field of SEM. For example, the fibre orientation distribution of non-woven fabrics can be determined using fast Fourier transform (FFT) and Hough transform (HT) [4]. The FFT is an especially popular algorithm and many papers have been published on the use of it. However, due to its complexity and a lack of fast hardware, real-time analysis had largely been impossible or impractical in the past, i.e. it was only feasible to perform FFT on images off-line. In 1997, with an advanced central processing unit (CPU) — the Pentium Pro, it was only possible to achieve a refresh rate of

about 0.6 frames per second for an 8-bit 1024 $\times$ 1024 image [5]. The enhancement of CPUs has enabled faster frame rates and more recently, the development of graphics processing unit (GPU) has taken image analysis to a different level.

The GPU was originally designed to efficiently manipulate data in order to accelerate the rendering of 3D images on displays. Depending on the position, pixels in a 3D image may require different processing to achieve effects such as lighting, blurring and fogging. This is achieved by breaking down the image into a massive number of fragments and processing each fragment individually. The processes happen independently but may share the same logical sequence of control, and this pattern is named single instruction multiple data (SIMD). A GPU consists of a large array of processing cores, with each of them using SIMD to process a block of fragments.

The characteristic of the GPU allows it to outperform central processing units (CPUs) when performing algorithms that manipulate data in parallel. Take the dot product between two vectors of size 1000 as an example, the processing cores on the GPU may be 100 times slower than the CPU, but if 1000 of them work in parallel and each computes the multiplication of one element from each vector, the overall speed will be 10 times faster. This has allowed computer vision programs that were previously impossible or computationally too expensive to build. For example, a wearable mediated reality device that make computer-generated information appear to the user as though it was anchored in the real world [6].

The goal of the project is to develop software tools based on fast computation provided by the GPU, to support interactive real-time diagnosis of SEM images for the purpose of assisting the operator or automating procedures, with a focus on the use of FFT.

II. Overview

III. Real-time histogram equalisation for improving image contrast

IV. Real-time fast Fourier transform for evaluating image focusing and astigmatism

The quality of an SEM image is affected by aberrations. While some exist because of the fundamental properties of the microscope and are difficult to get rid of, some can be completely eliminated by adjusting relevant settings. Two important ones are focus and stigmator control, which directly affect the resolution and astigmatism of the image, respectively. Fig. 2 illustrates the effect of wrong focus and stigmator settings.

Focus determines the focal point of the electron probe. When the focal point is far from the surface of the specimen, the incident electrons interact with the specimen in a larger area. As a

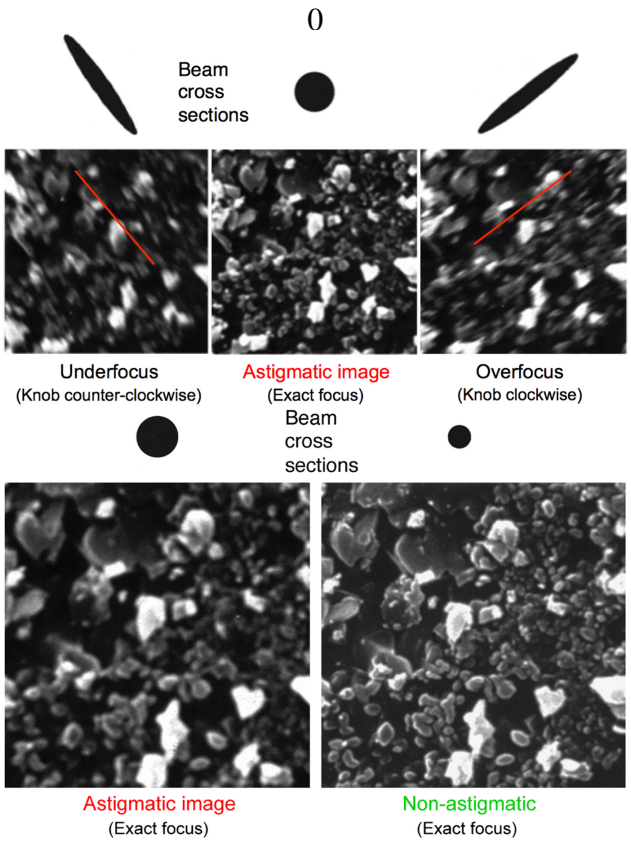

Fig. 2: Sample astigmatic SEM images [7].

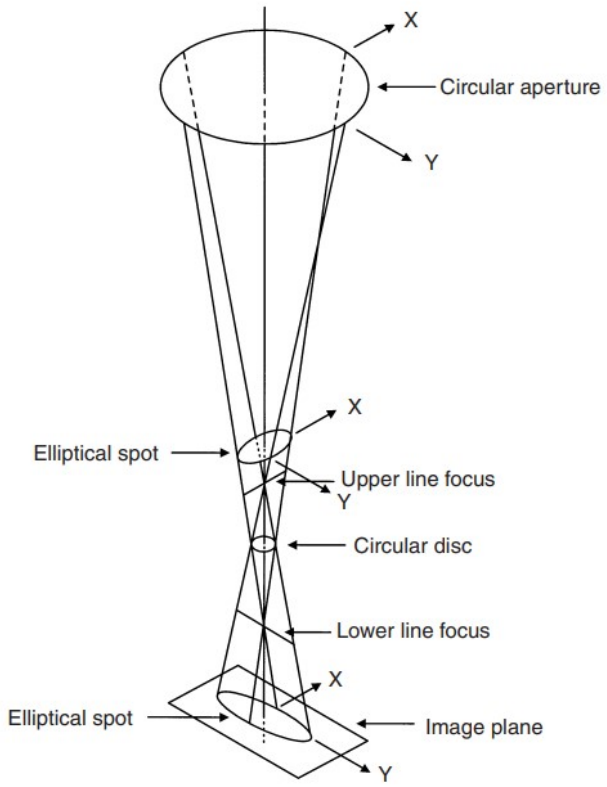

Fig. 3: Uneven focus of the SEM.

result, spots near each other produce signals of closer magnitude. This makes the image appear blurry.

Stigmators are used to compensate for astigmatism. Astigmatism arises due to imperfections in components of the SEM, and describes uneven focus in the electron probe, as shown in Fig. 3. When the electron probe is out of focus, astigmatism makes the incident electrons interact with the specimen in an elliptical area, and thus makes the image appear stretched. When the electron probe is in focus, astigmatism makes the image appear blurry.

Although experienced SEM operators can often find the right settings for focus and stigmator control in a short time, it may not be as straightforward for new users. Sometimes, the surface being observed may have a complex structure and makes adjusting even harder. The complexity arises because any judgement of an image is based on what the operators see through their eyes, which is rather subjective. Intensive training and practical experience are often required for an operator to become efficient in using the SEM.

V. Automatic focusing and astigmatism correction algorithm

VI. Conclusions

References

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