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Polarisation Contrast in Scanning Microscopy

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We will begin by discussing the differences between polarisation contrast imaging in conventional and confocal systems and show that because of the fundamentally different imaging properties of the two systems, the extinction coefficient is finite in a conventional system even with perfect polars, whereas an "infinite" extinction coefficient is to be expected in a confocal system.

We will then discuss the axial response of high numerical aperture systems and show that a polarisation effect leads to an asymmetric response when the objective lens numerical aperture is greater than the refractive index of the specimen. The effects are reminiscent of spherical aberration but occur even with the best corrected lenses.

In order to take advantage of polarisation effects to enhance the contrast due to a particular object property it is necessary to realise that the optical field reflected from the specimen contains all the information about the object that can be included in the image. The optical imaging system then determines how this field is compressed into a single pixel brightness value. The conventional microscope imaging system performs this compression by essentially integrating the intensity in the exit pupil of the objective lens over the area of the exit pupil whereas the confocal system ef-fectively integrates the amplitude over the pupil area. In both cases the information from the object is the same but the imaging system has caused it to be "averaged" over the pupil in a different way. This inevitably causes a good deal of information about the object to be obscured. This drawback can be overcome if we modify the imaging system to obtain images whose contrast is determined by the form of the field at the exit pupil of the objective lens. In its simplest form we could form an image of the exit pupil which is ,of course, the basis of conoscopy.

In order to illustrate our approach we will concentrate on a variety of planar thin film structures. The conoscopic patterns in these cases are particularly sensitive to polarisation effects and variations in film thickness. Indeed if we consider a simple system consisting of a layer of silicon dioxide deposited on a silicon substrate it is relatively easy to use a curve fitting approach to determine the film thickness. In this case it is only necessary to analyse the data corresponding to the s or p polarised beams. If we consider other angles within the conoscopic pattern then it is possible to extract the full ellipsometric data about the specimen. In effect the conoscopic system is acting as a photometric or micro-ellipsometer.

Since the intensity in conoscopic pattern depends only on the Fresnel reflection coefficients r_s or r_p along mutually perpendicular diameters and on a combination of the two along other diameters that the pattern will, in general, not be angularly symmetric. We may take advantage of this to enhance image contrast. In a conventional system the asymmetry integtates out and an image intensity proportional to $|r_s|^2+|r_p|^2$ results. We will demonstrate a polarisation difference imaging technique which enhances the asymmetry and leads to and image where variation in film thickness are clearly visible.

We will further consider imaging between crossed and parallel polars and suggest a variety of spatial filters which may be inserted into the optical system to enhance specific image contrast. The role and choice of wavelength and objective lens numerical aperture will also be discussed.