1 Scanning Electron Microscopy Results

A number of samples of metallic-black and metallic-bright films were sent to the Centre for Microscopy Characterisation and Analysis (CMCA) at UWA for study. In this section we will present and discuss some of the images produced by CMCA. These images provide an invaluable aid to understanding the structural differences between metallic-black and metallic-bright films.

Figure 1 shows a comparison of an Au-Black and Au-Bright film imaged using a scanning electron microscope (SEM). The intensity of each pixel is proportional to the total current of secondary electrons scattered from the surface at that point from the metal in the film (the current due to the Si substrate has been subtracted from the image), which is in turn proportional to the density of metal at the considered point.

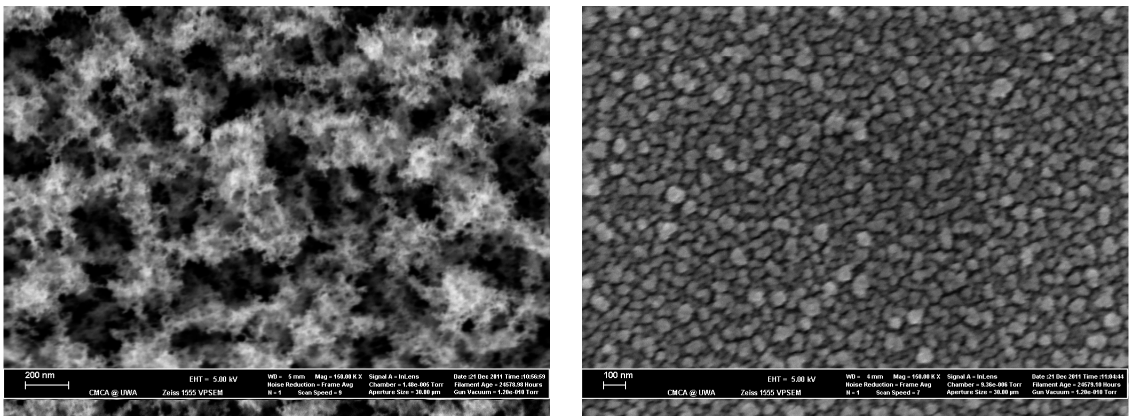

Figure 1: **2500 x 1900nm SEM images of Au-Black (left) and Au-Bright (right) deposited on Si** Preparation pressures were 2×10^{-2}mbar and 1×10^{-6}mbar respectively.
The films are sufficiently thick to be able to observe the colour with the naked eye.

The structural differences between the two films are striking. The surface of the Au-bright film appears to consist of a layer of well defined metallic nanoparticles with sizes ranging from 20 to 100nm. In contrast, the Au-black film shows a highly irregular pattern, of interconnected strands of material. This pattern has lead some researchers to refer to metallic-black films as "smokes" [].

Fourier Analysis of SEM Images

Fourier Analysis of the above SEM images can be used to provide more quantitative information about the structural differences between the two films.

The two dimensional Discrete Fourier Transform is given by:

$$F(k_x, k_y) = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x, y) e^{\frac{-2\pi i}{N}(k_x x + k_y y)} \tag{1}$$

Where $f(x, y)$ is a discrete data value (in this case the pixel intensity of the image) co-ordinates (x, y), $N \times N$ are the dimensions of the image, and $F(k_x, k_y)$ gives the Fourier Coefficient. The largest frequencies that can be obtained from an $N \times N$ image are

Equation (1) actually gives the Fourier coefficients of the infinite periodic extension of $f(x, y)$. If $f(x, y)$ is not periodic, then applying (1) introduces extra high frequency components due to sharp discontinuities at the boundaries. A window may be applied to f to ensure periodic boundary conditions; however, as windowing ... no window has been applied in this case.

Figures **??** and **??** show the amplitude plots of the DFT for each of the SEM images in figure 1. Since the phase plots give little additional information, they will not be presented or discussed here.

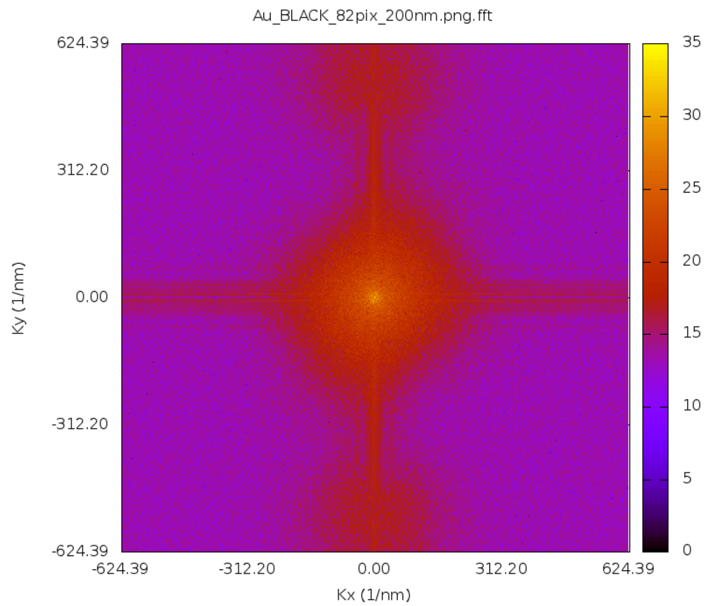

Figure 2: Amplitude density plot of DFT for Au-Black SEM image

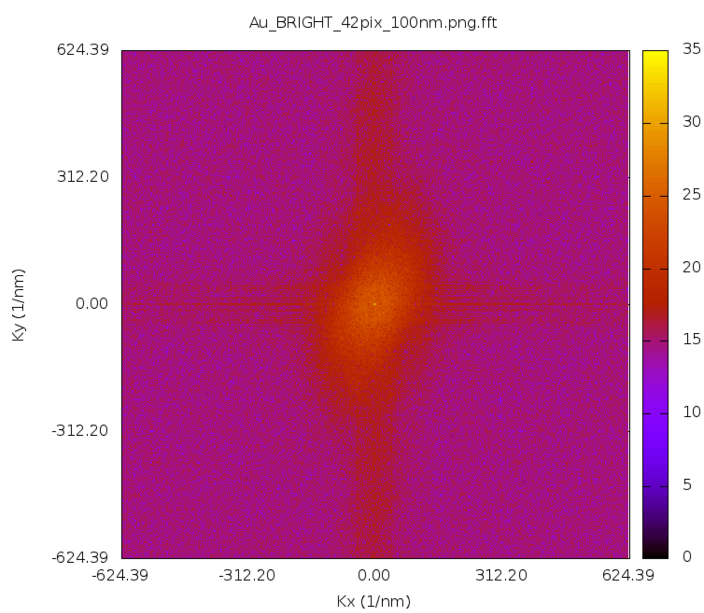

Figure 3: Amplitude density plot of DFT for Au-Bright SEM image

Higher magnification images confirm