Nanocharacterisation of the structural and luminescence properties of materials in the scanning electron microscope

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The performance requirements for next-generation materials, with applications spanning the aerospace, automotive, oil and gas, electronics and lighting industries, demand pioneering manufacturing techniques combined with innovative characterisation tools. The structural properties of materials play a vital role in the performance of critical components and it is important to understand such properties down to the sub-micron scale. For example high temperature operation of gas turbines is affected by the crystal orientation of the nickel-based single-crystal super alloys from which they are made; the optical efficiency and lifetime of UV LEDs is strongly dependent on the type and density of structural defects such as dislocations present in AlGaN thin films.

The novel scanning electron microscopy techniques of electron backscatter diffraction (EBSD); electron channelling contrast imaging (ECCI) and hyperspectral cathodoluminescence imaging (CL) can provide complementary information on the structural and luminescence properties of materials rapidly and non-destructively with a spatial resolution of tens of nanometres. EBSD provides orientation, phase and strain analysis, whilst ECCI is used to determine the planar distribution of extended structural defects such as threading dislocations and stacking faults over a large area of a given sample. CL provides information on the influence of crystallographic defects on light emission, either specific defect-related luminescence or dark spot features where carrier recombination at defects is non-radiative. CL can also provide information on the composition of alloy thin films used in the manufacture of light emitting devices, e.g., the AlN content in AlGaN thin films.

In this talk I will describe the EBSD, ECCI and CL techniques and give some examples of their application to real material problems. In particular I will illustrate the advantages of acquiring coincident EBSD/ECCI/CL data to the understanding of nitride semiconductor structures. For example Fig. 1 below shows an electron channelling contrast image and a hyperspectral CL intensity map of the UV emission from approximately the same region of a $Al_{0.8}Ga_{0.2}N$:Si thin film. Note that the presence of dislocations (black-white spots), revealed by ECCI, lead to a reduction in the luminescence. In particular dislocations with a screw component appear as dark spots in the CL image.

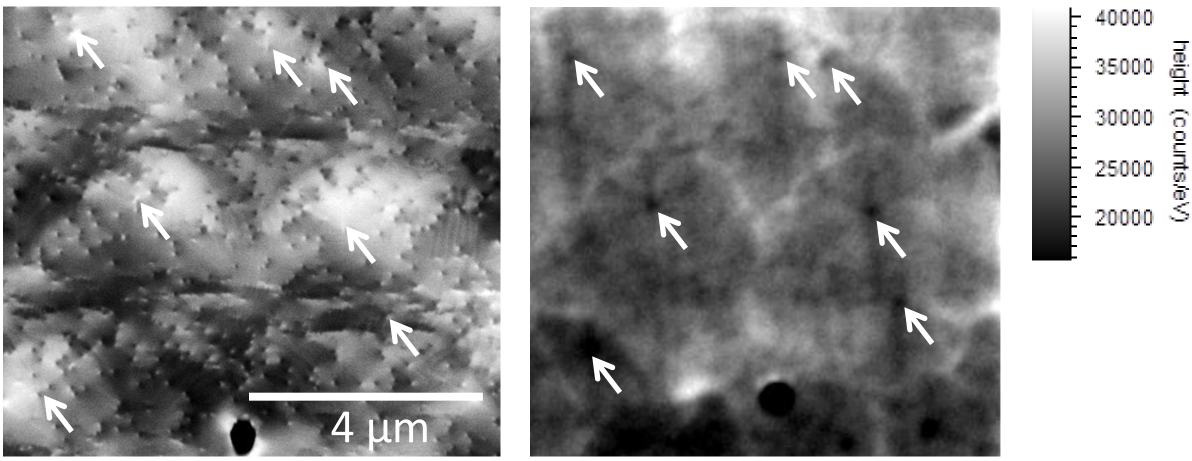

Figure 1: (a) Electron channelling contrast image (b) UV Cathodoluminescence intensity image.
Arrows indicate threading dislocations with a screw component (as identified by ECCI) which appear as dark spots in the CL image.

I will also describe how advances in instrumentation, e.g., digital direct electron imaging detectors, can provide exciting opportunities for new applications for these techniques.

For more information see: http://gan-sem.phys.strath.ac.uk/