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Characterization of Materials Properties by EBSD, EDS and AFM

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Modern manufacturing faces a number of technological challenges to produce advanced materials with tightly controlled specifications while increasing productivity and reducing environmental impact. These demands are met through the use of new processes and developing materials with very specific, well-characterized properties. This requires increasingly sophisticated levels of analysis in order to correlate and understand the properties of a material (mechanical, electrical, thermal, etc.) with its microstructure and composition.

The relationship between the microstructure and the materials properties is well-known. Examples include the Hall-Petch relationship, where strength is inversely dependent on the square root of the grain diameter [1] and the transformation-induced plasticity effect in multiphase steels, where the fraction and size of the retained austenite influences the strength and toughness. Therefore microstructure characterization is fundamental in understanding materials properties. This understanding allows developing new materials as well as predicting, modelling and troubleshooting the performance of these materials during their service life. This knowledge is increasingly important in a large range of industries and research areas. These include: metals research and processing, speciality metals and engineered materials, renewable energy and solar cell, microelectronics and geological research. As a result collecting and correlating a range of analytical data from complementary techniques enable a complete overview of a sample and its material properties. This study will discuss the potential of using EBSD, EDS and AFM together to better understand and predict the properties of materials.

Electron backscatter diffraction (EBSD) coupled with energy dispersive spectrometry (EDS) analysis on a scanning electron microscope is increasingly the technique of choice for advanced materials characterisation. EBSD combined with EDS can be applied to analyse a materials microstructure in detail. This includes identifying phases, measuring phase fraction and phase relationships, identifying crystal orientation with preferred orientation or texture components, and characterising grain morphology and deformation. The crystallographic orientation determined by EBSD can also be used to calculate mechanical properties such as the Young’s modulus. Figure 1 shows an example where the Young’s modulus map of a Cu sample was calculated using the third-party MTEX software [2]. The calculations are based on the elastic stiffness tensor for the copper [3], the average crystallographic orientation of each grain and a tensile direction. The map provides a visualization of the local stiffness distribution and valuable information to understand the resistance to elastic deformation.

Atomic force microscopy (AFM) is another powerful technique in nanomechancical characterization. This is a surface specific analytical technique, which generates very high-resolution topographic images of a surface, depending on the sharpness of the tip. As well as topographic images it can provide nanoscale information on chemical, mechanical (modulus, stiffness, viscoelastic, frictional), electrical and magnetic properties. An example is shown in Figure 2, here an elastic modulus map of a tin/lead alloy solder is overlaid on a topographic image [4]. The different tin and lead rich regions are identified with distinctly different modulus values.

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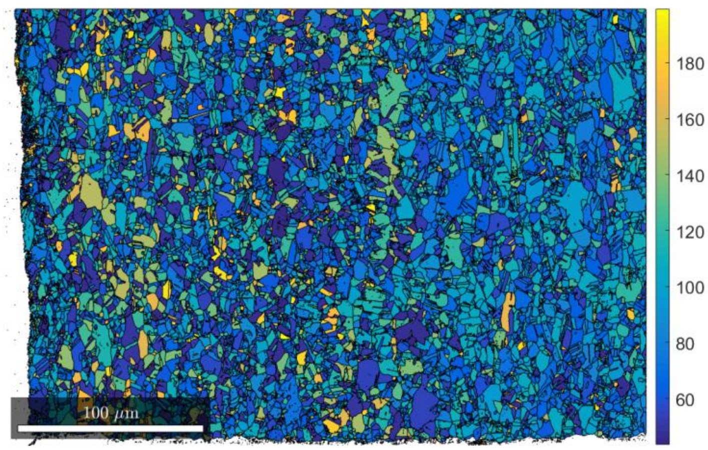

Figure 1. Young's modulus map from a Cu sample (values in GPa), determined from crystal orientation measured by EBSD (20 kV, Symmetry detector, 200 nm step size, 350 µm x 240 µm scanned area). Young's modulus is calculated assuming a tensile direction along the x-axis.

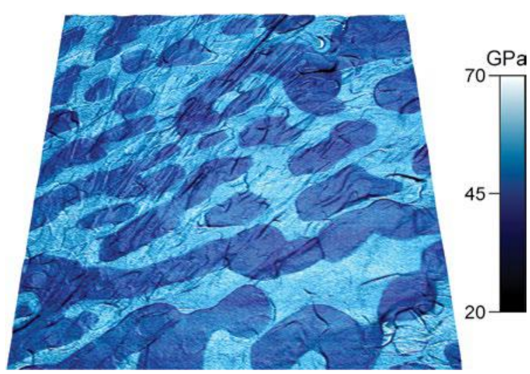

Figure 2. Elastic modulus map overlaid on topography of a tin/lead alloy solder measured by AFM (Cypher S AFM, Cypher S AFM, 1.5 Hz line scan rate with blueDrive™ photothermal excitation, 8 µm x 8 µm scanned area). Tin-rich (softer) and lead-rich (harder) regions can be identified.

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