Nano-Characterization of Nanomaterials Using Electron Microscopy

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The concept of nanotechnology was introduced by 20th-century celebrated Physicist Richard P. Feynman, who proposed using 1 nm^3 size clusters as "computer bits" [1, 2]. He noted the inadequate spatial resolution of the transmission electron microscope (TEM), which could not meet the challenges of imaging and characterizing the objects down to single nanometer-size clusters. Understandably, Feynman argued that the spatial resolution of TEM instruments should be improved [2]. Albeit unrelated, there have been consistent efforts to improve the resolution and capability of TEM instruments. In this regard, the significant developments introduced into TEM Instrumentation include spherical aberration correctors, high throughput X-ray dispersive spectroscopy (EDS) detectors, counting mode electron energy loss spectrometers (EELS), and pixelated array direct electron detectors [3, 4]. With the help of such correctors, contemporary TEMs routinely provide atomic-scale imaging and elemental and chemical analyses of samples [5]. For instance, a TEM's four-dimensional scanning transmission electron microscopy (4DSTEM) mode allows quantifying the microscale residual stresses in the range of tens of nanometers (Figure 1). Similarly, STEM-EDS mode can investigate the morphological and chemical properties of nanocomposites synthesized by combining nanoparticles (NPs) with 2D materials (Figure 2). Additional examples of nanoscale analysis of 2D materials with a TEM can also be noted.

References

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[2] R. P. Feynman, Engineering and Science, 22 (1960).
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[4] S.J. Pennycook, Ultramicroscopy, 123, 28 (2012)
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Figures

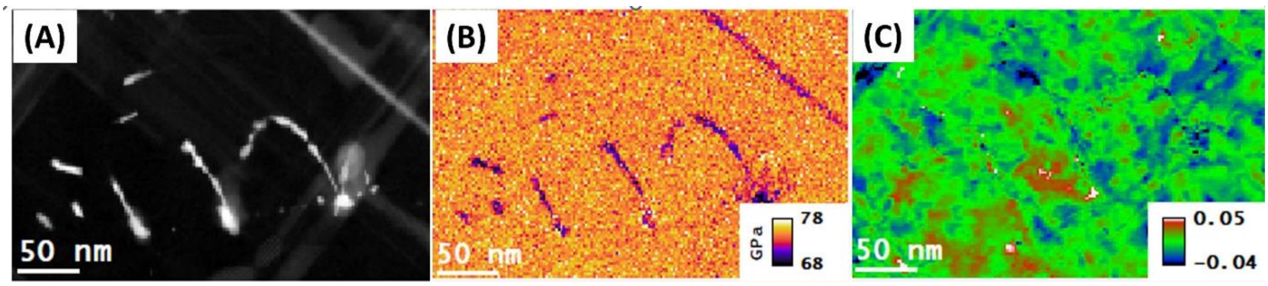

Figure 1: Nanoscale mapping of mechanical properties of Al2024 alloy. (A) DF-STEM Image. (B) Young's modulus map was generated at a 3 nm pixel size using the STEM-VEELS mode of a TEM. (C) The strain map was also generated at a 3 nm pixel size using the 4DSTEM mode of TEM.

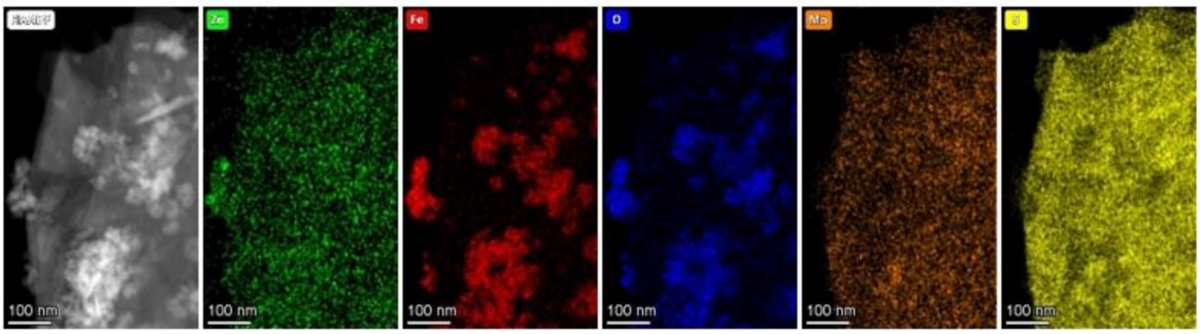

Figure 2: Morphological and elemental analysis of zinc-ferrite and molybdenum disulfide nanocomposite carried out using STEM-EELS mode of a TEM.