

Microstructure of Glidcop® AL-60 Conductor used in Pulsed Magnets

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Pulsed magnets require conductors with both high mechanical strength and high electrical conductivity in order to achieve ultrahigh-magnetic fields. One of these conductors currently used in the MagLab's pulsed magnets is Glidcop® AL-60, a copper conductor strengthened by alumina (Al_2O_3) particles. The properties of these sorts of composite materials are often dictated by its microstructures. As such, to understand the mechanical behavior of AL-60 and prevent unexpected magnet failure, magnet engineers and materials scientists must understand the microstructure of magnet conductors in detail.

Transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM) image the microstructure of AL-60, in particular, the alumina particles that are responsible for the high mechanical strength. Researchers find a large range of alumina particle sizes, from 10nm to 500nm of two structural types: stable $\alpha\text{-Al}_2\text{O}_3$ (**Fig. a**) and metastable cubic $\eta\text{-Al}_2\text{O}_3$. The $\eta\text{-Al}_2\text{O}_3$ nanoparticles were of triangular shape (**Fig. b**) with a well-defined crystal orientation relative to the Cu matrix.

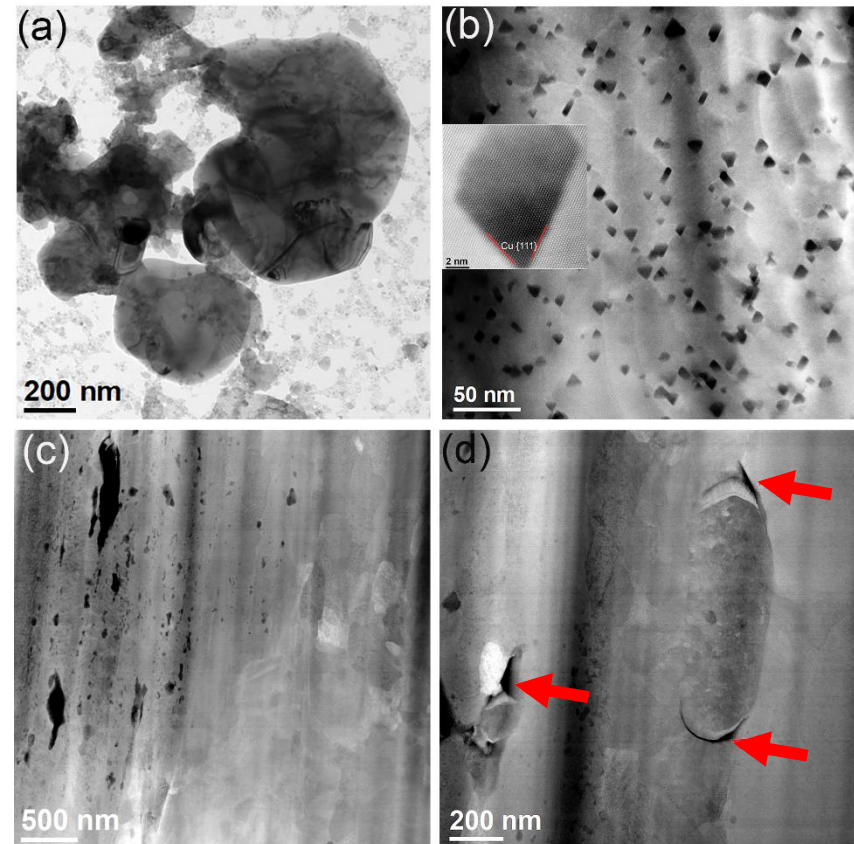
Dislocations are observed around the $\eta\text{-Al}_2\text{O}_3$ particles, which suggests that dislocations were unable to cut through alumina particles during conductor deformation. Regions with no alumina particles (**Fig. c**) suggest local weak mechanical strength. Finally, microcracks found near large $\alpha\text{-Al}_2\text{O}_3$ particles (Fig. d) presumably reduce the fatigue life of the material, which can be a limiting factor in the lifetime of pulsed magnets.

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Electron microscope images of Glidcop® conductor, showing (a) the large $\alpha\text{-Al}_2\text{O}_3$ particle; (b) the small $\eta\text{-Al}_2\text{O}_3$ particles; and (c) cold-drawn wire showing both a region of large Al_2O_3 particles of irregular shapes and a region with no Al_2O_3 particles. (d) STEM image of microcracks associated with large Al_2O_3 particles after a tensile test of Glidcop® wire. Note that cracks form at the end of the particles, as indicated by the red arrows.