High strength Copper-Chromium-Zirconium conductors for pulsed magnets

R. Niu [1], V. Toplosky [1], W. Starch [1], T. Adkins [1], I.R. Dixon[1], J.W. Levitan [1], J. Lu [1], D. N. Nguyen [2], and K. Han[1]
1. Florida State University; 2. Los Alamos National Laboratory

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Pulsed magnets achieve the highest non-destructive magnetic fields by carrying immense electrical currents that generate substantial heating and mechanical stress on the conductor. *One MagLab goal to advance its newly-commissioned pulsed magnets that are very popular with users by developing a conductor that features the difficult-to-achieve combination of electrical conductivity greater than 75% of the International Annealed Copper Standard (IACS) and strength greater than 500MPa.* Such a conductor would find applications in the next-generation mid-pulse magnets (large magnets that enable longer-duration pulses lasting 50 to 500 msec) and the outer coils of duplex pulsed magnets (nested pulsed magnets that are powered by independent capacitor banks to achieve higher magnetic fields). In order to optimize conductivity and strength, MagLab engineers and materials scientists investigated Copper-Chromium-Zirconium (Cu-Cr-Zr) alloys subjected to various deformation and aging treatments.

Researchers found that an optimized deformation and aging treatment produced a high density of Cr precipitates (dark contrast in the main image of the **Figure**) that are uniformly distributed throughout the Cu matrix. The precipitate size varied from 1 to 4 nm, much finer than the grain size (300nm) in the Cu matrix.

This optimized treatment contributed to higher conductivity than has ever been achieved in commercial Cu-Cr-Zr alloys. In the MagLab's recent collaboration with Hypertech, Inc. and Yantai Wanlong Vacuum Metallurgy Co., a Cu-Cr-Zr conductor with a cross-section of 4.0 x 5.5mm^2 and a continuous length of over 250 meters was fabricated. *This conductor reached conductivity higher than 80% IACS and strength greater than 550MPa. The MagLab will exploit this achievement to (1) wind a mid-pulse magnet to reach fields greater than 55T, and (2) upgrade duplex pulsed magnets to reach fields greater than 80T*.

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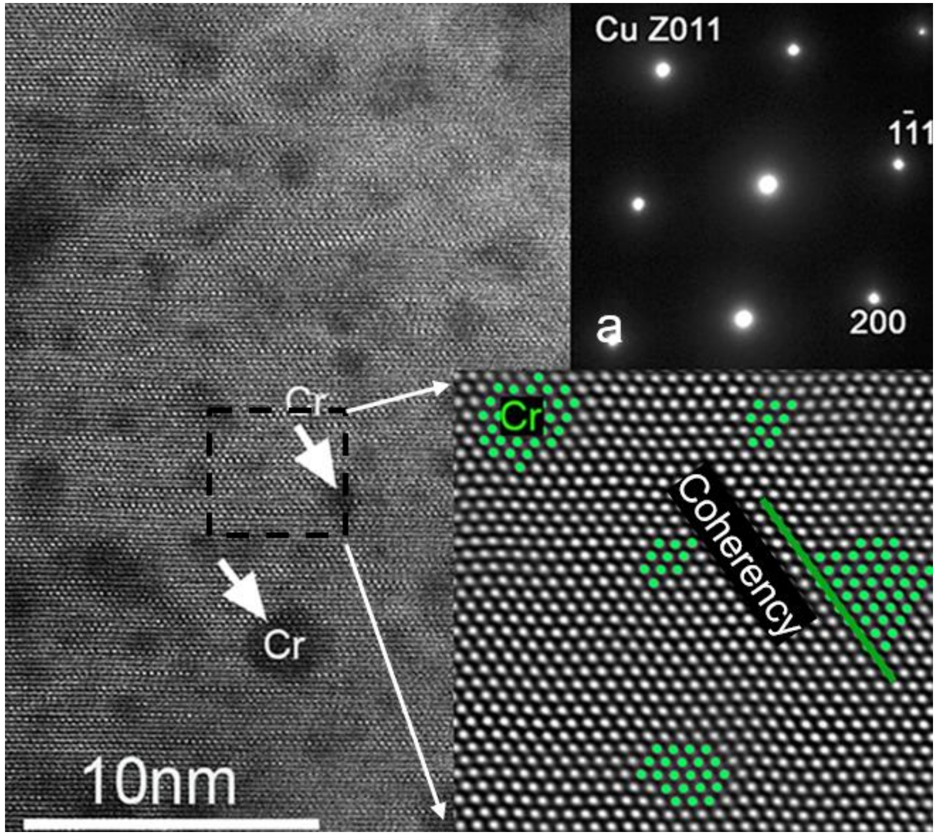

Figure: An atomic-resolution, high-angle annular dark-field image of an aged sample showing uniformly distributed Cr precipitates (dark contrast in main image. A fast Fourier transformed image (lower inset) shows coherent interfaces (such as the one indicated by a green line) between the Cu matrix and the precipitates (shown in green). Due to the coherent structure between the precipitates and the matrix, only one set of diffraction spots appears in the selected area diffraction pattern (top inset).