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Cu/Nb nanocomposite wires processed by severe plastic deformation for high pulsed magnets: effects of the nanostructure on the resistance to high stress, high temperature and irradiation

Copper-based high strength and high electrical conductivity nanocomposite wires reinforced by Nb nanotubes are prepared by severe plastic deformation, applied with an Accumulative Drawing and Bundling process (ADB), for the windings of high pulsed magnets. The ADB process leads to a multi-scale Cu matrix containing up to N=854 (52.2 106) continuous parallel Nb tubes with diameter down to few tens nanometers. After heavy strain, the Nb nanotubes exhibit a homogeneous microstructure with grain size below 100 nm. The Cu matrix presents a multi-scale microstructure with multi-modal grain size distribution from the micrometer to the nanometer range. The use of complementary characterization techniques at the microscopic and macroscopic level (in-situ tensile tests in the TEM, nanoindentation, in-situ tensile tests under neutrons and high energy synchrotron beam) shed light on the role of the multi-scale nature of the microstructure in the recorded extreme mechanical properties.

In addition, combined implantation/irradiation experiments (dual beam with 10keV He and 4 MeV Au) have been performed in-situ in the TEM on these Cu/Nb nanocomposite metals: while the coarse Cu channels exhibit a very rapid degradation with the formation of large bubbles at grain boundaries and inside Cu grains, the Cu/Nb nanocomposite regions exhibit much higher resistance to defect formation. In particular, nanometer-size bubbles first form at Cu-Nb interfaces while the Nb nanostructures interior remains bubble-free up to even larger dose.

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