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Mon-Af-Or4-06: High strength - high conductivity silver nanowire-copper composite wires by spark plasma sintering and wire-drawing for non-destructive pulsed fields

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Copper-based conductive wires with both a high strength and a high electrical conductivity could find applications in aerospace and power engineering as well as in niche scientific applications such as materials for the production of high-field pulsed magnets. Indeed, in order to produce non-destructive fields, the coils must be wound of wires with a very high mechanical strength to resist Lorentz forces. LNCMI-Toulouse produces some of the most intense non-destructive pulsed magnetic fields in the world with a European record of 98.8 Tesla and aims at reaching more than 100 Tesla.

For several years, LNCMI and CIRIMAT have been exploring the design and preparation of novel copper-based nanocomposite wires, including the present silver nanowire-copper wires.

Silver nanowires were synthetized and mixed with a commercial micrometric copper powder. Samples containing 1, 5 and 10 vol.% silver were prepared. Copper and silver-copper cylinders (diameter 8 mm, length 33 mm) prepared by spark plasma sintering the corresponding powders serve as precursors to wire-drawing. The diameter of the cylinders is reduced by wire-drawing at room temperature, in several passes, thus producing progressively finer wires (diameter in the range 1-0.2 mm).

The copper grains show a lamellar microstructure with ultrafine grains (200-700 nm for a 0.5 mm diameter wire) elongated over several micrometers. The silver nanowires are dispersed along the grain boundaries of copper.

The electrical resistivity and tensile strength were measured at 293 K and 77 K. The tensile strength for the composite wires is more than twice the value measured for the corresponding pure copper wires. Interestingly, the wires containing only 1 vol.% silver offer the best combination of high strength (1100 ± 100 MPa at 77 K) and low electrical resistivity (0.50 μΩ.cm).

Thus, the present 1 vol.% silver-copper composite wires compare favorably with silver-copper alloy wires containing about 20 times more silver.

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