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Silver nanowires - copper composite wires for non-destructive pulsed fields : importance of avoiding the formation of a silver/copper alloy relative to the electrical resistivity and the tensile strength

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A commercial micrometric Cu powder is mixed with Ag nanowires (diameter 0.2 μm , length 30 μm) synthesized in-house, in order to prepare a powder with a Ag content of 1 vol. %. Two powder batches are prepared for consolidation into cylinders (diameter 8 mm, length 33 mm) by spark plasma sintering.

One cylinder is sintered at 400 $^{\circ}\text{C}$, where the solubility of Ag in Cu is below 0.1 vol. %, which allows one to obtain a composite microstructure with pure Ag nanowires dispersed in a pure Cu matrix. The other cylinder is sintered at 600 $^{\circ}\text{C}$, where the solubility of Ag in Cu is equal to about 2.4 vol. %, which allows the Ag nanowires to dissolve into the surrounding Cu volume to form Cu/Ag alloy nanowires.

The diameter of the cylinders is reduced by wire-drawing, in several passes, thus producing progressively finer wires (diameter in the range 1-0.2 mm). Wires with ultrafine Cu grains (200-700 nm for a 0.5 mm diameter wire) elongated along the drawing axis are prepared. The nanowires (pure Ag or Cu/Ag alloy) are dispersed along the Cu grain boundaries.

Both kind of wires show a similar ultimate tensile strength (1100 MPa at 77 K), reflecting an equivalent strengthening effect provided by the pure Ag and Cu/Ag alloy nanowires.

However, the electrical resistivity of the Cu/Ag-Cu wires (0.56 $\mu\Omega\cdot\text{cm}$ at 77 K) is significantly higher compared to that of the Ag-Cu wires (0.49 $\mu\Omega\cdot\text{cm}$ at 77 K). This shows that despite the very local nature of the Cu/Ag alloy, its formation is to be avoided by controlling the sintering conditions, which thus have to be changed depending on the chosen Ag content.

Pure Ag nanowires - Cu composites wires are to be preferred in order to obtain the most suitable properties for high magnetic fields.

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