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High strength and conductivity CuAg micro-composites by accumulative drawing and bundling process

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Background

As a candidate material for high field pulsed magnets, Cu-Ag materials exhibit well conductivity properties with compatible tensile strength. Moreover, the properties are rarely affected by the wire specification, which is suitable for the outside conductors of magnets.

Objectives

The repeated bundling and drawing is crucial for refining the filaments and bundling the filaments together. And heavily deformation will promote the eutectic structure and the secondary-precipitation into nano filaments , which benefit the mechanical properties greatly without aggravating conductivity obviously.

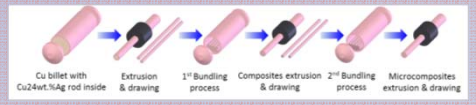
Conclusion

- A multi-scale CuAg microcomposite was prepared by ABD process.
- It is believed that nano-fibers of Proeutectic Cu and eutectic act as reinforced phases while multi-scale Cu-i layers provide high conductivity during ABD process.
- And the good performance could be exhibited by the samples with a UTS of 510MPa and a conductivity of 98.5% IACS.

Methods

Accumulative Drawing and Bundling

I. Cu-Ag ingot were prepared by vacuum induction melting.
II. The ingot was inserted into a Cu billet, and the whole part was transformed to wires by extrusion and drawing .
III. The wires were cut into many segments and bundled into a new billet. Then the billet was experienced repeated process as introduced above.
IV. In final, the wires embedded multi-filaments have been produced.



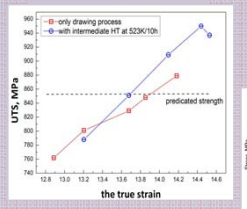
Experimental Procedures

- Cu-24wt.%Ag ingot were prepared by means of vacuum induction melting process at 1423K under condition of 5×10^{-2}Pa.
- The procedures are repeated for two times (583 filaments for the first bundling and 425 filaments for the second one)
- The microstructures were observed by SEM (JSM-6700) and HRTEM (JEM-2100F).
- Tensile tests are measured by Instron 5800 at room temperature.
- Transport characteristics are determined by the four-probe method and RRR here is defined as $R_{293\,K}/R_{77K}$.

Properties

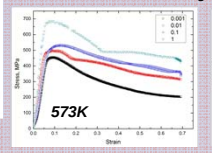
Strength and Conductivity

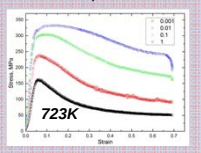
1st compositing sample



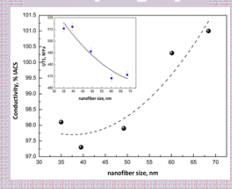
$$\sigma=f_{matrix}\cdot\sigma_{matrix}+f_{proeutectic}\cdot\sigma_{proeutectic}+f_{eutectic}\cdot\sigma_{eutectic}+f_{precipitates}\cdot\sigma_{precipitates}$$

The balance between the materials hardening and dynamic recovery (recrystallization) will be decisive for the flow stress state during thermal compression.





2nd compositing sample

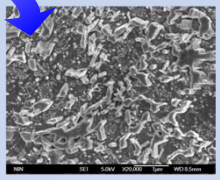


For 2nd sample, the UTS could reach 570MPa while the conductivity is about 90%IACS.

Microstructure

casting

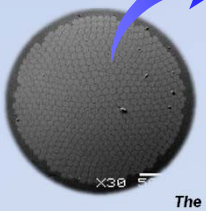
extrusion



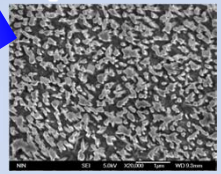
It is found that the spacing of the colonies decreased to 0.2μm after extrusion and drawing process for Cu-24wt.%Ag wires. The net-like colonies have been broken up into smaller net structure during the process.

Microstructure evolution

1st compositing



CuAg Nano filaments

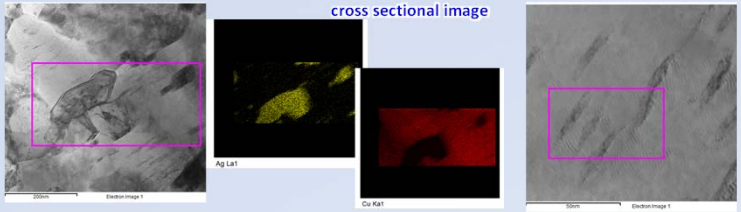


The net-like junctions have transformed to single nano-fibers. In compared with eutectic in Cu-Ag casting alloys, eutectic filaments in microcomposites distribute more regularly and the size is below 40nm.

Texture development during process

- It is found that the typical intensity of (111) peak are dominated as the increase of the true strain.
- All with BCC structure, eutectic Ag exhibits lower value of I(200)/I(111) ratio than that of Cu matrix in material.
- It attributes to the introduction of multi-scale Cu layers which experienced different processing strain.

cross sectional image



- The length-width of the filament is 3.5. the filaments lapping is observed among matrix. While the size of proeutectic copper is beyond 120nm.
- And the second precipitations are observed around the filaments. The thickness is about 4nm, which concentrated in the proeutectic areas.