Electronic devices, Electric vehicles

Advanced copper sintered composites strengthened by oxide nano-particles

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Abstract

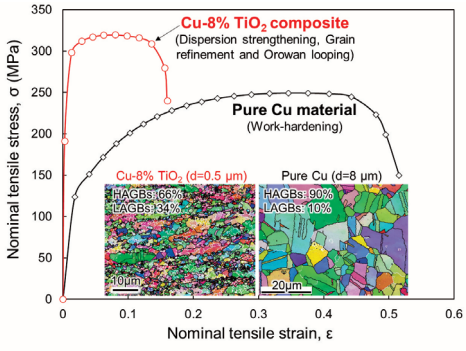
The trade-off between strength and ductility has been a dilemma in copper (Cu) matrix composites. In this work, we introduce a way of strengthening copper matrix composites containing TiO_2 nano-particles with remarkable ductility. The Cu–8wt%TiO_2 composites were fabricated using the powder metallurgy route with spark plasma sintering (SPS) for different holding times incorporating hot extrusion. The sintered composites for longer holding times showed an inhomogeneous distribution of large dispersed particles located mostly along the grain boundaries. However, tensile strength was improved compared with pure copper while ductility was reduced. In contrast, after hot extrusion, a homogeneous distribution of reinforcement particles and grain refinement concurrently triggered strong strengthening and enhanced ductility. The contribution of synergistic strengthening mechanisms, i.e. Hall–Petch strengthening, Orowan pinning, dislocation density and load transfer effect, was studied and the key strengthening mechanisms were elucidated. It was found that composite yielding was strongly affected by sintering time, particulate size and interparticle spacing so that the composite via SPS for 30min. presented the excellent yield strength of 290 MPa, about 72% above pure copper.

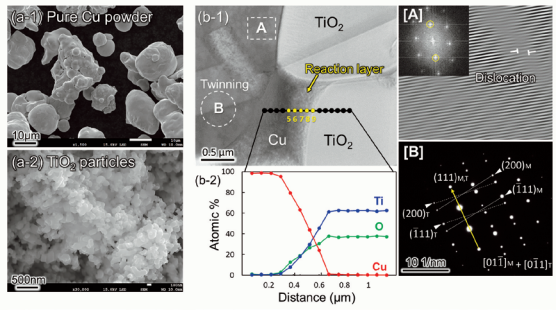
Background & Results

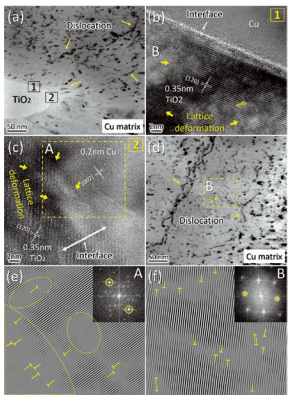
The superior electrical and thermal conductivity of copper has triggered this metal to become a promising choice to be utilized in an extremely wide range of applications such as heat exchangers, combustion chamber liners, rocket nozzles, high voltage switches and the electrode for resistance welding. However, the low intrinsic strength of copper and its alloys limits their use in applications that require high mechanical properties. In this regard, researchers have recently striven to come up with ways to enhance the strength of copper while retaining its unique properties. There are two common strengthening routes to obtain high-performance copper composite: precipitation-hardening and ceramic particulate-reinforced composites such as oxide or boride fine particles. Both methods are effective to enhance the strength improvement of Cu alloys, but the elongation remarkably decreases at the same time. That is, the conventional materials design is limited in their trade-off balance between strength and ductility. To achieve the main objective in this study meaning the interface bonding improvement between oxide nano-particle reinforcement and Cu matrix for high strength and enough elongation, the solid-state sintering process was employed to fabricate Cu-TiO_2 composite alloys via powder metallurgy route. The strengthening and deformation mechanism was clarified by the experiment using in-situ SEM tensile test and theoretical analysis, in particular grain refinement, dislocation hardening and Orowan looping effects were dominant in the remarkable strength improvement.

Significance of the research and Future perspective

An improved strength-ductility balance is significantly effective for both weight reduction and high reliability of electronic components made by Cu alloys, which mainly used in automotive and aircrafts. In particular electric vehicles are equipped with a lot of Cu material parts. In the near future, we will start a cooperation with the industrial companies for practical use of this advanced Cu composites.







Patent

Treatise Bahador, Abdollah; Umeda, Junko; Kondoh, Katsuyoshi et al. Synergistic strengthening mechanisms of copper matrix composites with TiO_2 nanoparticles. Materials Science & Engineering A. 2020; 772: 138797. doi: 10.1016/j.msea.2019.138797.
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URL http://www.jwri.osaka-u.ac.jp/~dpt6/index_en.html

Keyword copper alloys, powder metallurgy, nanocomposites, mechanical property