論 文 の 要 旨

題 目 Thermal and Mechanical properties of Short Carbon Fiber dispersed Aluminum Composites

（短炭素繊維分散アルミニウム複合材料の熱物性および機械的性質）

氏 名 GUO YING

The rapid development of science and technology has put forward higher and higher requirements on the comprehensive performance of materials, and the development of high-performance aluminum(Al) matrix composites is an urgent problem at present. Considering the worldwide initiatives for sustainable development and energy conservation, the development of composites with excellent thermal conductivity, high strength and high plasticity has become an important topic in recent years. The type and size of the reinforcement, the preparation method of composites and the subsequent thermal processing treatment all have an impact on the microstructure and mechanical properties of the material. Therefore, all aspects need to be fully considered when designing Al matrix composites.

Spark plasma sintering (SPS) technology is widely used due to its ability to remove the oxide film on the surface of metal powder and promote the bonding of the matrix and reinforcement. Carbon-based reinforcements such as carbon fibers and carbon nanofibers have excellent thermal properties and combining them with an Al matrix can result in a material with good thermal conductivity. Exploring suitable ways to enhance the wettability and interfacial bonding of the reinforcement to the matrix is crucial, given the influence of interfacial structure on thermal conductivity. Additionally, the effect of differences in reinforcement diameter on the thermal properties and microstructure of the composite is also a key issue that needs to be elucidated. Since the addition of reinforcements inevitably destroys the integrity of the Al matrix and negatively affects the plasticity of the composites, addressing the challenge of maintaining the thermal properties and strength of Al matrix composites while improving their plastic deformation capacity has become an urgent issue.

To solve the above problems, in this study, pure Al was used as the matrix, and copper-coated carbon fibers and uncoated carbon fibers were selected as the reinforcement for the preparation of composites by SPS, and the effects of copper coating on the microstructure, mechanical properties and thermal properties of Al matrix composites were analyzed. To investigate the mechanism of the influence of reinforcement diameter on the composites, short carbon fibers, and carbon nanofibers were used as reinforcements for comparison. And the design of gradient structured Al matrix composites was used to enhance the strength and plasticity of the composites. The microstructure analysis of the composites was performed using electron backscatter diffraction (EBSD), scanning electron microscopy (SEM), and transmission electron microscopy (TEM). The mechanical properties of the composites were analyzed using microhardness, nano-hardness, and room temperature tensile equipment. The thermal conductivity of the composites was also measured and analyzed. The mechanisms of copper coating, hot rolling, reinforcement diameter, and gradient structure design on the microstructure and mechanical properties of the composites were investigated in depth, providing a theoretical reference for the application and development of Al matrix composites.

The conclusions of this thesis are summarized as follows:

1) The Cu-coating improves the wettability of short carbon fiber and Al matrix, resulting in

better electrical conductivity of the mixed powder of copper-coated carbon fiber and Al powder. The Cu-coating increases interfacial coherence, promotes interfacial bonding, and enhances interfacial strength. The protection of the SCF structure by the Cu-coating leads to higher yield strength and thermal conductivity. During the hot rolling, the uncoated SCF reacted severely with the Al matrix and generated the harmful phase Al_4C_3. Hot rolling promotes the arrangement of SCF along the rolling direction, and the yield strength of Cu-SCF/Al increases by 121.93%. The thermal conductivity is improved by 6.64%, close to the ideal value calculated by the layered parallel model. The analysis of the texture evolution clarifies three dynamic recrystallization mechanisms of SCF/Al and Cu-SCF/Al before and after hot rolling.

2) The SCFs are uniformly dispersed in the Al matrix and generate continuous amorphous carbides with the Al matrix at the interface. The VGCNFs are aggregated due to their small diameters and exist as agglomerates, and only a small amount of VGCNFs generate amorphous interfacial products with the Al matrix. The thermal conductivity value of SCF is lower than that of VGCNF, but has higher heat transfer efficiency. The aggregation of VGCNF negatively affects the heat transfer efficiency. SCF/Al has higher yield strength, but lower plasticity. In contrast, VGCNF has a smaller diameter, which makes VGCNF/Al have higher plasticity.
3) The addition of SCF results in a greater degree of plastic deformation of the Al matrix during hot rolling, leading to a recrystallized mode with a Rot-Gauss component promoting nucleation mechanism. The VGCNF clusters are less obstructive to shear band motion, and the main recrystallization mechanism is the transformation of shear band grains into recrystallized grains. The meritocratic growth characteristic of P component leads to more large P component grains in Pure Al and VGCNF/Al, which have a negative effect on mechanical properties; The strong resistance to deformation and crack extension of the Rot-Gauss component results in a high yield strength of SCF/Al.
4) The reinforcement in the gradient composites layers is uniformly distributed. The gradient composites has good bonding interfaces between the 3% CF-3% SiC and 3% SiC-10% SiC layers. The difference in reinforcement type and volume fraction leads to different microstructure characteristics of the gradient composites' layers. Gradient composites simultaneously has high yield strength and plastic deformation ability. The fine grain strengthening effect due to SiC gives the high strength of gradient composites. The promotion of dislocation formation by SiC and the crack hindrance by gradient structure are the main reasons for the high plastic deformability.
5) The changes of grain orientation and grain size at the interlayer interface lead to high interlayer stress, which further causes interface failure and cracking. The semi-coherent interface between SiC-Al and CF-Al promotes good interfacial bonding. As the addition of SiC particles introduces more interfaces and leads to smaller grain size and higher grain boundary density, the thermal conductivity values of gradient composites in the axial and horizontal directions are lower than those of Al and CF/Al. The difference in grain size and content between CF and SiC leads to in situ recrystallization for the 3% CF layer, while the 3% SiC and 10% SiC layers are mainly nucleation-growth recrystallization mechanisms. The different recrystallization mechanisms result in the different mechanical properties of CF and SiC layers in gradient composites to a certain degree.