Improving the interfacial strength of silver-graphite-copper electrical laminates

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Abstract

Silver-graphite electrical contacts are essential in high-performance switching due to their conductivity, arc resistance, and self-lubricating properties. Combining silver's conductivity with graphite's anti-welding characteristics makes them ideal for circuit breakers and industrial switches. To reduce silver usage, copper is introduced as a bilayer system, offering cost savings. However, copper's immiscibility with graphite causes graphite accumulation at the interface during sintering, leading to delamination. To address this, an interlayer containing silver-coated copper particles was introduced, mitigating graphite accumulation and enhancing adhesion between silver-graphite and copper layers. Electron backscattered diffraction analysis confirmed the formation of Cu_3Ag intermetallic at the interface, demonstrating a simple method to improve the adhesion of silver-graphite-copper laminates.

Introduction

Electrical contacts are switches that are used to make or break electrical connection. This necessitates high electrical conductivity to operate efficiently. Materials that have high conductivity such as silver, copper, and in some cases, gold are used to manufacture these products. Due to highly repetitive application, high wear resistance is required. Unfortunately, the highly conductive materials also tend to be soft, requiring addition of additives such as graphite or tungsten to improve the wear properties, especially in silver contacts. The high cost of gold renders its use impractical in most common products. Silver is preferrable for possessing the highest electrical conductivity but is also costly. Consequently, copper tends to be economically preferred material despite having lower conductivity as compared to silver. A silver-copper composite has been of some interest to manufacturers. A layered structure of copper (Cu) and silver with graphite additive (Ag-C) has been proposed, but unfortunately results in delamination of the two post-sintering. Despite the similarities of Ag and Cu, which include the same FCC crystal structure, and are both highly conductive, there is poor wettability of copper on graphite which leads to little to no diffusion between the two. This results in accumulation of graphite at the silver-graphite (Ag-C) and Cu interfaces.

Some improvements methods for C-Cu wettability found in literature include alloying copper or adding elements such as Fe, W, Mo, Cr, and Ti[1-6]. Unfortunately, these elements possess lower electrical conductivity than Ag or Cu, making these methods unfavorable for exceptionally conductive applications. Other methods include cold and hot pressing of graphite flakes and copper[7]. Further, various methods of electroless deposition of copper onto graphite have been utilized. A particularly interesting paper by Mousavi and Pourabdoli investigated the use of an entirely silver coated copper system for electrical contact applications[8]. It has been shown that warm compaction of Ag/Cu leads to improved wear resistance[9]. But as it currently appears, there have been no published studies on the use of Ag-C-Cu systems. Therefore, this study looks to investigate the use of Ag-C-Cu layered composites for electrical contacts.