Influence of Phase Transformations on Strength and Electrical Conductivity in Aluminum/Calcium Heavily Deformed Metal-Metal Composites

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ABSTRACT

Few (bi-metallic) metal-metal composite (MMC) materials possess combined properties of high strength, high electrical conductivity, and low density. One such MMC, Al/Ca, provides this unique combination of properties through the development of a blended elemental PM method to form wire that, for example, can be wound into cable for power transmission. By combining analysis of microstructure, calorimetry, and high energy (synchrotron) in situ XRD, we gained insight into phase transformation kinetics resulting in formation and stabilization of the unique properties inherent in Al/Ca heavily deformed metal-metal composites (DMMCs). It was found that tensile strength can exceed 300 MPa, derived from formation of an Al/Ca monoclinic intermetallic compound (IMC) formed at the interface of Al and Ca. This interface introduces a barrier to diffusion of Al into Al/Ca IMC between 150-200°C., retarding the formation of additional IMCs until 275°C. Ultimately, these formation and stabilization kinetics establish that the upper operating temperature limit of Al/Ca DMMCs conductors exceeds 200°C.

INTRODUCTION

With current government policies, the global demand for new conductor cables will reach 16 million kilometers by 2030 to facilitate the expansion and development of power grids [1,2]. Additionally, most North American overhead electricity transmission lines, predominantly established from the end of World War II to 1970s, are reaching the end of expected lifetime [3]. This is leading to an extraordinarily high demand for new powerlines and technologies capable of greater power throughput or ampacity. With the ever-increasing demand for electricity and an inevitable need for new and replacement powerlines, utilities are required to increase the ampacity of the established transmission and distribution networks and are burdened, thereby, with the strain of seamless implementation . In fact, this next decade is projected to incur an 80% increase in new line construction globally over the previous decade [1]. An approach to ease this burden is to invest in new sustainable advanced materials for High Voltage Direct Current (HVDC) overhead powerlines, which possess superior electrical conductivity per mile with sag resistant attributes. The most reliable advanced material in production for this application was introduced in 2005, by 3M, as an aluminum conductor composite reinforced (ACCR) cable consisting of Al-alloy outer conducting strands with metal-matrix composite (MMC) core strands, composed of an Al-matrix with Al_2O_3 reinforcement filaments. ACCR cable, with the highest temperature and strength stability in the industry, also has proven to be the most reliable material for overhead conductors [4]. However, the