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M4Or1B-06: [Invited] Lightweight clad bimetal conductors for cryogenic applications

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Clad bimetal conductors combine two diverse metals or alloys that are metallurgically bonded to achieve functional advantages that cannot be obtained with a single metal. The selection of metals or alloys to use is determined by end-use requirements such as electrical, mechanical, and chemical properties. Common clad materials consist of a core, such as aluminum, nickel, steel, or copper alloys, along with a clad layer of silver, gold, copper, or titanium. Applications of these clad material combinations include high-frequency electrical coils, electrical switches, immersion heaters, processing vessels, and material-handling equipment. In this research, we present and explore more unconventional combinations to study and assess novel lightweight clad bimetal conductors (LCBC).

Emerging electrical aircraft topologies that generate thrust by the combustion of liquid hydrogen require electrical components with high efficiency and low masses. The onboard use of cryogenic-cooled lightweight clad bimetal conductors in electric machines or cables represents significant mass reduction and increased gravimetrical power density capabilities. In addition, under cryogenic conditions, these conductors' enhanced current-carrying capabilities enable lower voltage levels. Other applications for LCBC include high-energy physics, superconducting magnets, inductor windings, satellites, and rockets.

The alkali metals sodium, lithium, and potassium exhibit the highest conductivity per unit density of any other metal at room temperature. At 77 K, beryllium and lithium exhibit even higher conductivity per unit density values. These metals present promising lightweight conductor solutions, yet they vigorously react with water (alkali metals) and are toxic (beryllium). These chemical properties hinder the use case of these elements as single metal conductors. On the other hand, containing these metals within an inert clad layer adds functional advantages. For example, copper on lithium creates chemical resistance, promotes electrical conductivity, improves mechanical properties, and facilitates soldering. Other interesting metals included in this study are aluminum, gold, silver, magnesium, and titanium.

This research provides an overview of the properties and applications of lightweight clad bimetal conductors for cryogenic systems. It discusses end-use requirements for onboard electrical aircraft cryogenic applications and compares weight, cost, and performance. It comprehensively studies the core and clad layer material's chemical, electrical, and mechanical properties by (1) employing the Ashby method to study the conductors' material by systematically relating material performance requirements to quantifiable material properties and (2) a finite element analysis to study lightweight clad bimetal conductors' electrostatic and thermal characteristics. Lastly, careful consideration is given to the manufacturing processes and their challenges, given the properties of the conducting material.

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