Enhancing Aluminum Alloys with Piezoelectric Particles through Friction Stir Processing: A Study on Voltage Measurement and Polarization Direction

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This study presents a novel approach to create smart materials with enhanced sensorial properties by incorporating piezoelectric particles into an aluminum alloy using a solid-state processing technique called friction stir processing (FSP). The resulting composite material exhibits piezoelectric behavior, generating small voltages when subjected to mechanical strain. The research builds upon prior works investigating different aluminum alloys and piezoelectric particles, such as barium titanate and PZTs. Here, we focus on voltage measurement techniques, examining the feasibility of assessing voltage output from various surfaces and exploring the influence of polarization direction on the material's response. Voltage measurements have been performed between two opposite surfaces, limiting their applicability in scenarios where access to both sides is not feasible. To address this limitation, alternative voltage measurement configurations were explored, including measuring voltages between two points on the same surface. This investigation aims to broaden the practicality and potential use cases of the smart material by providing insights into voltage measurement methods applicable to real-world applications. The experimental approach involved incorporating piezoelectric particles into the aluminum alloy matrix through FSP, followed by a polarization process to align the particles' dipoles. The resulting composite, referred to as a Self-Sensing Material (SSM), exhibits enhanced piezoelectric properties and the ability to continuously monitor its own condition. By measuring voltage output from different surfaces and polarization directions, we gain valuable information about the material's response to external stimuli. The study evaluates the electrical voltage signals generated by the SSM under various strain stimuli. Through systematic experimentation, we assess the correlation between the material's response and different strain levels and loading conditions. Additionally, the influence of polarization direction on the voltage output is thoroughly investigated to understand its impact on the material's sensing capabilities. The findings from this research contribute to the development of smarter and more versatile materials with improved sensing abilities. The ability to measure voltages from various surfaces and polarization directions opens up new possibilities for applications in structural health monitoring and damage detection. Moreover, the enhanced mechanical properties resulting from the incorporation of piezoelectric particles through FSP make the SSM an attractive candidate for lightweight and durable structural components. Overall, this study demonstrated the feasibility and effectiveness of creating smart materials through FSP and offers valuable insights into optimizing their sensorial properties. The research outcomes pave the way for the practical application of such materials in diverse engineering fields, where real-time monitoring and non-intrusive sensing are crucial for ensuring component integrity and performance.