TAILORING POLYMERS FOR MECHANOCALORIC AND ELECTROCALORIC APPLICATIONS: CHALLENGES AND PROSPECTS

Erik Oda Usuda (erik.usuda@unifesp.br)

Laura Péres (laura.peres@unifesp.br)

Caloric effects represent a promising class of solid-state energy conversion technologies that reversibly convert external field energy, magnetic, mechanical, or electrical, into thermal energy. These effects are driven by intrinsic material properties related to structural, magnetic, or dipolar configurations that change under field application, inducing significant changes in entropy (?S) and temperature (?T). In recent years, polymers have emerged as a prominent class of caloric materials due to their high performance, cost-effectiveness, and processing versatility [1-4]. In mechanocaloric applications, large conformational changes and stress-induced crystallization in elastomers and thermoplastics allow for massive configurational entropy shifts. For instance, under uniaxial tension or pressure, these materials can exhibit temperature changes reaching up to 40 K at stress levels of approximately 400 MPa (in the case of Acetoxy Silicone Rubber) [2]. Similarly, the electrocaloric effect (ECE) exploits dipolar rearrangements in ferroelectric polymers, such poly(vinylidene difluoride) (PVDF)-based copolymers and liquid crystal polymers. These materials leverage field-induced phase transitions (e.g., paraelectric-to-ferroelectric) to promote substantial entropy and temperature changes (around 10 K) [4]. Despite their potential, organic caloric materials face critical challenges, particularly regarding their low intrinsic thermal conductivity and limited dielectric strength. Current research suggests that the pathway to superior electrocaloric performance lies in the synergistic optimization of thermal and electrical properties. Enhancing thermal conductivity requires improving phonon propagation, either by increasing chain alignment or incorporating high-conductivity fillers [3]. Concurrently, electrical optimization focuses on enhancing the breakdown strength and material stability through interface engineering [5]. This approach improves dipole mobility and enables ultrahigh entropy changes under lower operating fields. Looking ahead, the flexibility, lightweight nature, and scalability of polymers position them as ideal candidates for environmentally friendly, solid-state cooling systems. This work highlights the primary polymeric materials for caloric applications and outlines the prospects for their future technological integration.

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Palavras-chave: energy conversion materials; caloric effects; ferroelectric polymers; rubbers.