On lightweight shape memory vitrimer composites

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What is the outcome or accomplishment? (1-2 short sentences describing it and why it is transformative; 50-word maximum suggested)*

We prepared an shape memory vitrimer (SMV)-based syntactic foam to investigate the influence of hollow glass microbubbles (HGM) volume fractions on a broad set of properties. Four sample groups, containing 40%, 50%, 60%, and 70% HGMs by volume, were tested and compared to a control pure SMV group. A series of analyses and various chemical, physical, mechanical, thermal, rheological, and functional experiments were conducted to explore the feasibility of ultralight foams. Notably, the effect of HGM volume fractions on the rheological properties was methodically evaluated. The self-healing capability of the syntactic foam was also assessed for healing at low and high temperatures. This study proves the viability of manufacturing multifunctional ultralightweight SMV-based syntactic foams, which are instrumental for designing ultralightweight engineering structures and devices.

What is the impact? (1-2 simple sentences describing the benefits for science, industry, society, the economy, national security, *etc.*; suggested 50-word maximum)

This study bridges two critical gaps in the current understanding of SMP-based syntactic foams. Firstly, it introduces an innovative concept: the first intrinsic self-healing SMP-based syntactic foam utilizing a vitrimer matrix, marking a significant leap in the field of syntactic foams. Secondly, the study delves into a comprehensive analysis of how varying HGM volume fractions impact the mechanical and functional properties of the syntactic foam. By systematically exploring these fractions beyond the conventional 40%, the research sheds light on previously uncharted aspects of syntactic foam behavior and performance.
In essence, this research not only paves the way for the development of more efficient and versatile syntactic foams but also expands the horizon of knowledge in the field, setting the stage for future innovations and applications.

What explanation/background does the lay reader need to understand the significance of this outcome? (1-2 paragraphs that might include, for example, more on who, when, where; NSF's role; support from multiple directorates/offices; what makes this accomplishment unique; additional

intellectual merits; or broader impacts such as education, outreach, or infrastructure improvement that are integral to this outcome; suggested 150-word maximum)

Potential applications of SMP-based syntactic foams include using them as sandwich cores, deployable space structures, sealants in pavement and bridge deck joints, and loss circulation materials in the oil & gas and geothermal industries. Recent development includes SMP-based syntactic foams with multi-functionalities such as 3D printability, flame retardancy, strain sensing, and two-way shape memory effect.

In addition to shape memory, damage healing in polymer composites is also a highly valuable functionality. Damage healing can occur either extrinsically by adding an external healing agent or intrinsically within the polymer itself. Although SMP-based syntactic foams with extrinsic self-healing have been investigated, none of the reported syntactic foams have intrinsic self-healing capability to date. It is clear that the intrinsic self-healing capability of a syntactic foam depends on its polymer matrix. While intrinsic self-healing thermoset polymers have been a topic of intensive research over the years, vitrimer - a type of intrinsic self-healing thermoset polymer based on the adaptable covalent network (CAN) - has become one of the most studied intrinsic self-healing polymers. Since then, many outstanding studies on vitrimers have been conducted. Several new reversible covalent bonds have been introduced in the thermoset network, including, but not limited to, transesterification, transcarbamoylation, transamination (to vinylogous urethane or hindered urea), olefin metathesis, siloxane equilibration, boronate-diol exchange, radical disulfide exchange, radical thiyl-ally sulfide exchange, and phosphate ester exchange.