

Highly loaded magnetocaloric La(Fe,Si)13H powder composites for additive manufacturing: Characterization and modeling of field-induced phase transition

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Additive manufacturing is attracting increasing interest in the field of magnetic refrigeration to solve the problem of the brittleness of intermetallic magnetocaloric alloys. The formulation of a composite based on a thermoplastic binder loaded with La(Fe,Si)13H magnetocaloric powder and then its shaping by an innovative additive manufacturing process (by Fused Granular Fabrication) was carried out in a previous work [1]. To preserve the magnetocaloric properties of La(Fe,Si)13H powder, the composite must present the highest powder mass fraction, the rheological behavior best suited to 3D printing from pellets, and the process of preparation of the composite must not exceed the dehydrogenation temperature of the alloy of approximately 200°C. The result is a composite with a high magnetocaloric powder content (89% by mass), as well as the optimisation of certain parameters in the manufacturing and printing process. Various parts of highly charged magnetocaloric powder were printed. Their characterization reveals favourable properties, such as a porosity of $10.8 \pm 2\%$ present in the binder in the form of pore sizes $< 2.10^{-3} \text{ mm}^3$ and with a few voids of 4.10^{-3} mm^3 obtained by X-ray tomography, and, high magnetocaloric properties ($\Delta s = 9.3 \text{ J/K}\cdot\text{kg}^{-1}$). This communication will present the effects on the magnetocaloric properties of the manufacturing and printing process as well as those of the binder in the form of dilution of properties and retardation due to the additional mass of the binder. Initial DSC measurements carried out at various stages of the process show that there is no major difference in the transition temperature, as it is very close to the reference temperature given by the supplier of $290 \pm 1 \text{ K}$. They also show that the phase transition spread of 20 K is not influenced, or even delayed, by the presence of the binder for a slow heating rate of 3 K/min. Other DSC characterizations will be carried out with higher temperature velocities and under a magnetic field to identify the evolution of transition temperatures as a function of the field, i.e. the Clausius-Clapeyron diagram. Finally, magnetic characterizations using a VSM will complete these characterizations to ultimately identify the parameters of a model capable of predicting the phase transition induced by a magnetic field and developed by one of the authors in the context of the thermodynamics of irreversible processes [2-3].

References

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