Physical properties of supersilent, magnetically soft $(GaNi)_x$CoCrFe high-entropy alloys

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In a search for high-entropy alloys (HEAs) with functional physical properties emerging from their multi-scale structure, we have studied the $(GaNi)_x$CoCrFe ($x = 0.4$–1.6) system. We conducted a comprehensive characterization of the structure, microstructure, nanostructure, and chemical composition of the individual phases within the multi-phase alloys, and examined their magnetic, magnetostrictive, and electrical properties. Our findings indicate that these alloys are ferromagnetic and exhibit a unique combination of magnetic softness and negligible magnetostriction, identifying them as energy-efficient "supersilent" materials (inaudible to a human ear) for alternating-current (AC) electromagnetic applications in the audio-frequency range [1].

The alloys develop a two-phase structure consisting of a face-centered cubic (fcc) and a body-centered cubic (bcc) phase, with the fcc fraction decreasing as the $(GaNi)_x$ content increases, while the bcc fraction correspondingly increases. In the alloy with the highest GaNi content ($x = 1.6$), the fcc phase disappears entirely, and a minor $D0_3$ phase forms alongside the bcc phase. The ferromagnetism in these alloys is attributed to the highly nanostructured bcc phase, with Curie temperatures (T_C) ranging from 750 to 700 K, depending on x. The fcc phase, on the other hand, is not nanostructured and remains paramagnetic at room temperature, while it undergoes a spin glass transition at $T_f \approx 6.4\,K$ [1].

The magnetic softness and negligible magnetostriction observed in these alloys are both nanomagnetic phenomena. The magnetic and magnetostriction characteristics of the alloys with $x = 1.3$ and 1.6 render them particularly suitable for supersilent AC applications at audio frequencies.

References:

[1] J. Luzar, et al., Materials and Design **247** (2024) 113396; https://doi.org/10.1016/j.matdes.2024.113396