Unraveling Extraordinary Magnetoresistance in $GdFe_2Al_{10}$: A Comprehensive Exploration of Transport and Magnetism for Technological Applications

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I. MAGNETOCALORIC EFFECT ANALYSIS

In the magnetocaloric measurement shown in figure 1(a), we observe a sharp transition from positive to negative values as the temperature decreases, indicating strong antiferromagnetic correlations. At low temperatures and low magnetic fields, there is a small positive region, suggesting weak ferromagnetism, which is also evident in the $M(T)$ plot at low magnetic fields. In figure 1(b), the high-field magnetocaloric effect curves become entirely positive, indicating field-induced ferromagnetism.

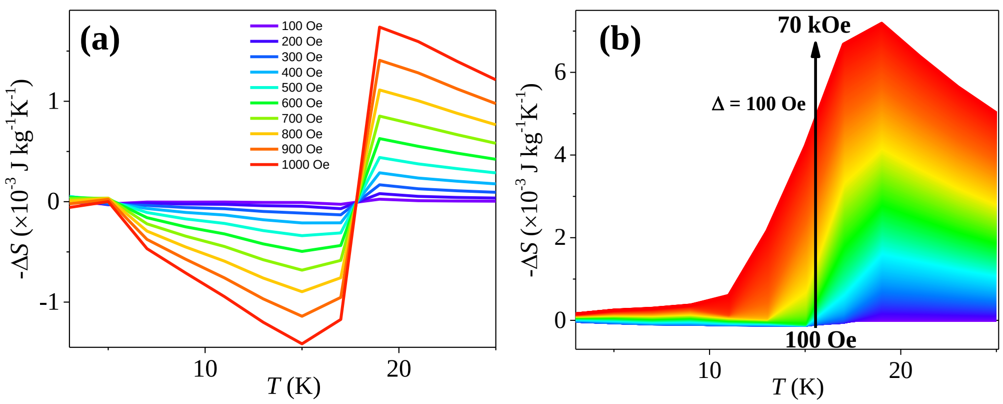

FIG. 1. (a) Temperature dependence of ΔS_M at (a) low magnetic fields and (b) high magnetic fields.

II. XPS AND ELEMENTAL MAPPING ANALYSIS

To understand the composition of the compound, we performed X-ray photoelectron spectroscopy (XPS) measurements and analysis. We conducted core-level XPS for Gd 4d in the range of 136 eV to 154 eV, Fe 2p in the range of 699 eV to 728 eV, and Al 2p in the range of 69 eV to 76 eV. All peaks were referenced (charge correction) to adventitious carbon at 284.8 eV. The background were fitted using a Shirley background. In the analysis of the Gd spectra, we deconvoluted it into two peaks at 147.2 eV and 141.9 eV, corresponding to Gd $4d_{3/2}$ and Gd $4d_{5/2}$, respectively [1, 2]. For Fe, after deconvolution, we identified two peaks at 720.1 eV and 706.9 eV, corresponding to Fe $2p_{1/2}$ and Fe $2p_{3/2}$, respectively [3, 4]. For Al, the deconvoluted peaks were at 72.9 eV and 72.3 eV, corresponding to Al $2p_{1/2}$ and Al $2p_{3/2}$, respectively [5, 6]. The energies of all the peaks closely match the previously reported charge-neutral energies. After calculating the area under each peak and applying the appropriate multiplicative factors, the atomic ratios of Gd, Fe, and Al were found to be 6.7%, 13.1%, and 80.1%, respectively, which are close to the ideal ratios of 7.69%, 15.38%, and 76.92%.

There is a well-known technique to assess the homogeneity of a compound, known as elemental mapping. Elemental mapping involves compiling highly specific elemental composition data across a sample area. If there is any inhomogeneity, or if certain areas are more populated with one element than another, it will be reflected in the elemental mapping. In figure 3, we present the elemental mapping of the constituent elements Gd, Fe, and Al in a particle nearly a micron in size. The figure clearly shows no significant contrast, confirming the homogeneity of the compound.

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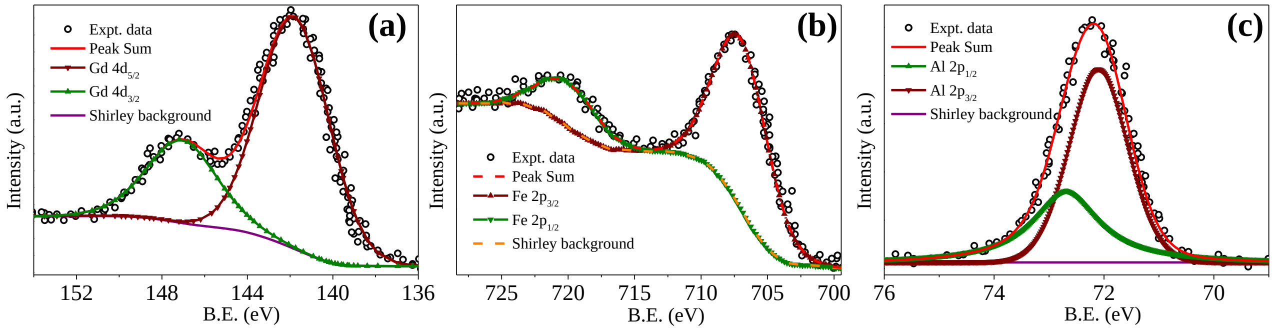

FIG. 2. (a) Temperature dependence of ΔS_M at (a) low magnetic fields and (b) high magnetic fields.

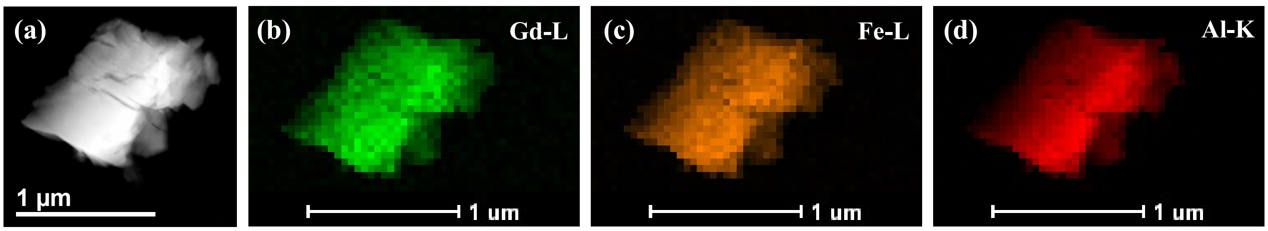

FIG. 3. (a) HAADF image of the particle on which elemental mapping was taken; Elemental mapping of (2) Gd-L, (c) Fe-L and (d) Al-K

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