Effect of Te substitution on magnetic properties of (Cr,Fe)S chalcogenide compounds

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[Introduction] Half-metallic ferromagnets (HMFs) are regarded as crucial materials for high-performance spin injectors and magnetoresistive devices in spintronics, owing to their 100% spin polarization at the Fermi level (E_{F}). Several half-metallic fully compensated ferrimagnets (HM-FCFiMs) have been theoretically predicted [1]. In these materials, antiferromagnetically coupled magnetic moments cancel each other out near the compensation temperature, enabling a small magnetization while maintaining half-metallicity. Recently, pyrrhotite-type (Cr,Fe)S was successfully synthesized and suggested to be a HM-FCFiM [2]. In this study, we investigated the effects of substituting S with Te on the crystal structure and magnetic properties of (Cr,Fe)($\mathrm{S}_{1-x}\mathrm{Te}_x$).

[Experimental Methods] Polycrystalline samples were synthesized by the solid-state reaction method. Elemental powders of Cr, Fe, S, and Te were mixed in nominal compositions and pressed into pellets. The pellets were sealed in evacuated quartz tubes, gradually heated to the reaction temperature, held for 24 hours, and subsequently quenched. The crystal structure was characterized by powder X-ray diffraction (XRD), and the phase morphology was observed using scanning electron microscopy (SEM). Magnetic properties were measured using a superconducting quantum interference device (SQUID) magnetometer.

[Results] It was confirmed that the single-phase formation temperature of (Cr,Fe)Te shifts to lower temperatures compared to (Cr,Fe)S. XRD measurements revealed that the diffraction peaks shifted toward lower angles upon Te substitution, suggesting the lattice expansion with maintaining the pyrrhotite-type crystal structure. Thermomagnetization curves of (Cr,Fe)Te measured under magnetic fields of 500 Oe and 5 kOe exhibited P-type ferrimagnetism, and the magnetization decreased with increasing Te content. For (Cr,Fe)(S,Te) compounds, characteristic behavior of fully compensated ferrimagnets was observed. The magnetic transition temperature was determined to be approximately 350 K. The compensation temperature (T_{comp}) is about 225 K, which corresponds to an increase of approximately 25 K compared to (Cr,Fe)S due to Te substitution. These results suggest the possibility of controlling the magnetic properties of (Cr,Fe)S through Te substitution.

References:

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