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J. Han

William B. Yelon
Missouri University of Science and Technology, yelonw@mst.edu

Naushad Ali

I. Dubenko

et. al. For a complete list of authors, see https://scholarsmine.mst.edu/phys_facwork/318

THE EFFECTS OF SUBSTITUTING IRON FOR MANGANESE IN $SmMn_6Ge_6$: MAGNETIC AND CRYSTALLOGRAPHIC PROPERTIES

J. Han,[a] G. K. Marasinghe,[a] W. J. James,[a] W. B. Yelon,[b] Ph.lH `ritier,[c] I. Dubenko,[d] and N. Ali[d]

[a] *Graduate Center for Materials Research, University of Missouri-Rolla, Rolla, MO 65409*
[b] *Research Reactor, University of Missouri-Columbia, Columbia, MO 65211*
[c] *Laboratoie des Mat`riaux et du G`nie Phsique, ENSPG, 38402 Saint Martin dH `res, France*
[d] *Department of Physics, Southern Illinois University at Carbondale, Carbondale, IL 62901*

In order to further understand the interaction between the magnetic moments of iron and manganese atoms in rare earth-transition metal intermetallics, we have investigated selected magnetic and crystallographic properties of several $SmMn_{6-x}Fe_xGe_6$ (0 # x # 1.5) solid solutions.

$SmMn_{6-x}Fe_xGe_6$ samples were prepared from elements of purity 99.99% or better by induction melting in a cold copper crucible followed by annealing at 750EC for two weeks. The phase purity of the samples was checked by X-ray diffraction (XRD). The bulk magnetic properties were measured on a SQUID or vibrating sample magnetometer. Information about the easy direction of magnetization was obtained from X-ray diffraction studies of powder samples that were magnetically aligned in-plane.

All of the $SmMn_{6-x}Fe_xGe_6$ samples crystallized in the hexagonal YCo_6Ge_6-type structure [1] with a small amount (<9% wt) of $Sm(MnFe)_2Ge_2$ as an impurity phase. The lattice parameters were obtained by Rietveld analysis [2] of powder XRD patterns. The unit cell volume decreases with increasing iron content at an average rate of 2.4% per substituted atom. This rate of contraction is almost twice that observed for $NdMn_{6-x}Fe_xGe_6$ [3]

Fig.1 shows thermo-magnetic data measured at an applied field of 2000 Oe for $SmMn_{6-x}Fe_xGe_6$ samples. The data for $SmMn_6Ge_6$, which is indicative of ferromagnetic ordering, is in good agreement with prior work [4]. The Curie temperature of $SmMn_{5.5}Fe_{0.5}Ge_6$, 446 K, is similar to that of $SmMn_6Ge_6$. However, the Curie temperature decreases rapidly as the iron content increases beyond x = 0.5, see Fig. 1. In addition, the thermo-magnetic data show another magnetic transition, in addition to that at the Curie Temperature, occurring around 50 K for the iron containing samples. The thermo-magnetic behavior of these samples are somewhat different from that reported for $NdMn_{6-x}Fe_xGe_6$ intermetallics [3].

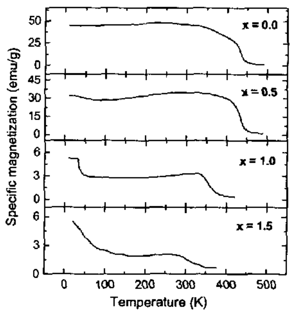

Fig. 1. Temperature dependence of the magnetization for $SmMn_{6-x}Fe_xGe_6$ intermetallics measured at an applied field of 2000 Oe.

The net of magnetization of $SmMn_{6-x}Fe_xGe_6$ intermetallics decreases with increasing iron content. The magnetization of $SmMn_{5.5}Fe_{0.5}Ge_6$ approaches that of $SmMn_6Ge_6$ at high applied fields, in excess of 7 and 3 T at 30 and 300 K, respectively. Here again, the magnetization drops drastically as the iron content exceeds x = 0.5. As a result, $SmMn_5Fe_1Ge_6$ and $SmMn_{4.5}Fe_{1.5}Ge_6$ do not magnetically saturate even at an applied field of 8 T. M vs. H data for $SmMn_{6-x}Fe_xGe_6$ samples are remarkably similar to that for $NdMn_{6-x}Fe_xGe_6$ [3]. As was the case for $NdMn_{6-x}Fe_xGe_6$ intermetallics, the magnetic moment of the iron sublattice appears to couple antiferro/ferrimagnetically with ferromagntically coupled moments of the manganese and samarium sublattices.

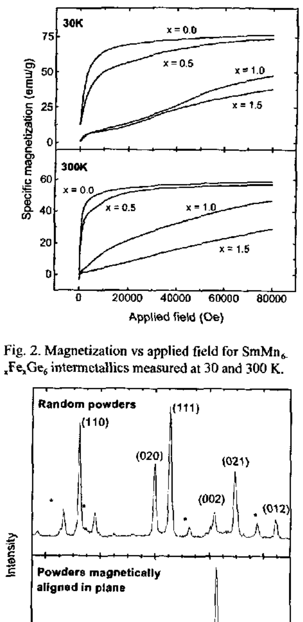

Fig. 2. Magnetization vs applied field for $SmMn_{6-x}Fe_xGe_6$ intermetallics measured at 30 and 300 K.

Fig.3 compares the XRD pattern for random powders of $SmMn_{4.5}Fe_{1.5}Ge_6$ with that of powders magnetically aligned in the reflecting plane of the XRD sample. The growth of the (002) reflection upon alignment indicates that the basal planes are preferentially oriented parallel to the reflecting surface of the XRD specimen. Taking in to account that the aligning field was parallel to the surface, we conclude that the net moment is parallel or close to being parallel to the basal plane of the unit cell. Similar results were observed for the other $SmMn_{6-x}Fe_xGe_6$ samples as well. In contrast, the easy direction of magnetization of $NdMn_{6-x}Fe_xGe_6$ intermetallics at 300 K was found to be the c-axis [3].

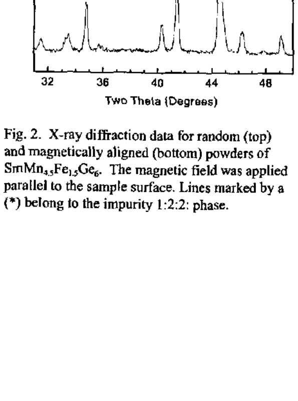

Fig. 2. X-ray diffraction data for random (top) and magnetically aligned (bottom) powders of $SmMn_{4.5}Fe_{1.5}Ge_6$. The magnetic field was applied parallel to the sample surface. Lines marked by a (*) belong to the impurity 1:2:2: phase.

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