第 529 回 物性セミナー・創発的物性物理研究拠点セミナー

Influence of Co substitution in Fe sublattice in RFe_5Al_7 (R = Dy, Ho) intermetallics

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Effects of the Co substitution for Fe on the magnetism of the strongly anisotropic ferrimagnets $DyFe_5Al_7$ and $HoFe_5Al_7$ (tetragonal crystal structure of the $ThMn_{12}$-type) are studied using magnetization measurements in static (up to 14 T) and pulsed (up to 58 T) fields at 2-300 K on single-crystalline samples grown in a triarc furnace by modified Czochralski method. Since the Co analogue of RFe_5Al_7 does not form, the homogeneity range of $RFe_{5-x}Co_xAl_7$ is expected to be limited. Solubility limit is found as x = 2.5 for both R = Dy and Ho. Within the homogeneity range the lattice parameter a decreases by ~0.7% whereas the parameter c stays constant. The easy-magnetization direction in all compounds is found to be the [110] axis, the [001] axis is the hardest direction.

In the ground state of $DyFe_5Al_7$, the magnetic moment of the Dy sublattice dominates. The spontaneous magnetic moment is 2.1 μ_B in $DyFe_5Al_7$ and increases linearly to 3 μ_B for x = 2 due to a decrease of the moment of the 3d-metal sublattice. With increasing temperature, a compensation of the Dy and 3d-metal sublattices is observed, above T_{comp} the total moment is along the 3d metal sublattice. The Curie temperature T_C linearly falls from 231 K for x = 0 to 120 K for x = 2.5. The observed strong decrease of T_C with increasing Co content is unexpected because the Co substitution for Fe in 3d-4f intermetallic compounds practically always leads to increase of the magnetic ordering temperatures due to the strengthening of exchange interactions. At the same time, T_{comp} = 93 K does not change within the homogeneity range. The compounds display anomalies for magnetic field applied along the easy magnetization direction. Two phase transitions are observed for $DyFe_5Al_7$ at the critical fields μ_0H_{cr1} = 30 T and μ_0H_{cr2} = 53 T. Both transitions display hysteresis and are of the first order. The pronounced difference between the curves measured for field applied along the [100] and [110] axes reflects a large anisotropy within the basal plane. $DyFe_{4.5}Co_{0.5}Al_7$ also displays two field-induced phase transitions of the first order, μ_0H_{cr1} is also 30 T, μ_0H_{cr2} shifts to 43 T. For the compounds with x = 1 and 2, the first-order transitions transform to a wide S-shape curve centered at 35 T. No field-induced transitions are observed along the [100] and [001] axes in all $DyFe_{5-x}Co_xAl_7$ compounds.

Qualitatively similar results were observed in $HoFe_{5-x}Co_xAl_7$ solid solutions: unusual strong decrease of T_C (from 216 K for x = 0 to 67 K for x = 2.5) and almost unchanged T_{comp}. (65 K - 72 K). Along the easy axis, two first-order field-induced magnetic transitions (at 17 T and 37 T) are observed for $HoFe_5Al_7$ and one transition at 27 T for $HoFe_4CoAl_7$. The magnetization curve has an S-shape for $HoFe_3Co_2Al_7$.

For $HoFe_5Al_7$, we studied substitution of Fe atoms also by Cr ones. In contrast to Co substitution where the number of 3d electrons increases, a substitution of Fe by Cr leads to a smaller number of 3d electrons. Nevertheless, T_C also decreases, moreover, very drastically. In $HoFe_4CrAl_7$ it is only 22 K.

5 研究科共同セミナーの認定科目です

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