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MAGNETIC AND ELECTRICAL PROPERTIES OF TERNARY PYRITE-TYPE $Cr_xCo_{1-x}S_2$ PHASES PREPARED AT HIGH PRESSURE

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ABSTRACT

New pyrite-type phases $Cr_xCo_{1-x}S_2$ ($0 < x < 0.4$) have been prepared at 65 kbars pressure in a tetrahedral anvil apparatus. Magnetic measurements indicate that the saturation magnetization decreases, while the Curie temperature increases, with increasing x. T_c reaches a maximum above room temperature at $x \simeq 0.3$. The magnetic data favor an arrangement in which low-spin Cr^{+2} is aligned antiferromagnetically to Co^{+2}. Electrical measurements show essentially temperature-independent resistivity with $\rho \simeq 10^{-4}$ ohm-cm.

Introduction

The pyrite-type compound CoS_2 is ferromagnetic (1,2) with a Curie temperature, T_c, of 118°K and a saturation magnetization, σ_s, of 40.8 emu/g. Solid solutions of CoS_2 with FeS_2 and with NiS_2 have been prepared at ambient pressure (3) and their magnetic properties studied (4,5). Both T_c and σ_s decrease to zero with increasing Ni content. With increasing Fe content, T_c and σ_s initially increase slightly, and then decrease to zero. Maxima for these two parameters occur at $T_c \simeq 146$°K for $Co_{0.75}Fe_{0.25}S_2$ and $\sigma_s \simeq 43$ emu/g for $Co_{0.95}Fe_{0.05}S_2$.

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Chromium forms a series of sulfides from CrS to $CrS_{1.6}$, which have crystal structures related to the NiAs type (6,7), but the disulfide is unknown. By the use of high reaction pressures, Cr was found to replace some of the Co in CoS_2 so as to give pyrite-type solid solutions $Cr_xCo_{1-x}S_2$. The purpose of this work was to determine the range over which formation of this solid solution occurred and to investigate the magnetic properties of these Cr-substituted compositions.

Experimental

Reactions were carried out at 60-65 kb pressure in a tetrahedral anvil press of National Bureau of Standards design (8). Samples were contained in a cylindrical boron nitride crucible surrounded by a graphite-sleeve resistance heater inserted in a pyrophyllite tetrahedron. The calibration points used to establish the pressure developed were the transitions Bi(I) → Bi(II) (25.37 ± 0.02 kbars), Bi(II) → Bi(III) (26.96 ± 0.18 kbars), Tl(II) → Tl(III) (36.69 ± 0.11 kbars), and Ba(II) → Ba(III) (59.0 ± 1.0 kbars). All compressions were made on the assembly at room temperature. The charge was then heated to the desired temperature which was measured with a Pt-Rh thermocouple, uncorrected for pressure effects. The thermocouple was placed at the center of the surface of the boron nitride crucible. The temperature at the ends of the crucible is about 30% lower.

High purity CrS, Cr_2S_3, Co, and S were used as reactants. These were ground together in the desired ratios and were pressed into pellets. In general, a small excess of S was used to enhance crystal growth, which occurred at the ends of the pellet because of the temperature gradient.

Reactions were carried out at various conditions. Usually the pellets were pressured to 65 kbars and the temperature was then raised to 1100°-1200° and held for about 2 hours. Subsequently, the samples were either quenched or cooled about