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Structure, Density, and Microhardness of $Co_{1-x}Ni_xTe$ ($0 < x < 1$) Solid Solutions

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Abstract—$Co_{1-x}Ni_xTe$ ($0 < x < 1$) solid solutions with the NiAs structure were prepared. The formation of a continuous series of solid solutions was confirmed by density and microhardness measurements.

INTRODUCTION

Magnetic characterization of solid solutions based on antiferromagnetic manganese, chromium, and nickel monoselenides and monosulfides [1, 2] shows that such materials may have an uncompensated magnetic moment. To gain greater insight into the physics of exchange interaction in the materials in question, it is of interest to investigate the magnetic properties of alloys based on compounds that undergo no magnetic ordering or are weak ferromagnetics, e.g., $Co_{1-x}Ni_xTe$. One would expect that CoTe and NiTe form a continuous series of solid solutions because both have the NiAs structure and their lattice parameters differ little [3, 4]: $a = 0.3894$ nm, $c = 0.5371$ nm in CoTe; $a = 0.398$ nm, $c = 0.538$ nm in NiTe.

In this paper, we report the preparation, structural properties, density, and microhardness of CoTe–NiTe alloys.

EXPERIMENTAL AND RESULTS

Synthesis and x-ray diffraction characterization. $Co_{1-x}Ni_xTe$ samples were prepared at $x = 0.1$ intervals from powder mixtures of Ni (99.99% pure), Co (99.99%), and Te (99.999%). The mixtures were sealed in silica tubes under a vacuum of 10^{-2} Pa and heated in a resistance furnace first at a rate of 0.4 K/min to 727 K and then at 4 K/min to 1330 K, where the melt was held for 12 h, followed by quenching in cold water. The resultant porous cakes were ground into powders, which were then pressed into pellets for annealing. We failed to obtain homogeneous monoliths by heat-treating the pellets at different temperatures for different lengths of time. Monolithic silver-gray $Co_{1-x}Ni_xTe$ materials could be prepared by hot pressing at 7 GPa and ≃1200 K for 30 s.

X-ray scans (MoK_α or CuK_α radiation) indicated that all of the materials were single-phase. The observed reflections could be indexed on the basis of a hexagonal, NiAs-type structure ($B8_1$ type, sp. gr. $P6_3/mmc$).

The composition dependences of lattice parameters (Fig. 1) demonstrate that, with increasing x, a rises linearly from 0.3923 ± 0.0006 to 0.3990 ± 0.0006 nm, while c decreases only slightly, from 0.5369 ± 0.0009 nm in CoTe to 0.5353 ± 0.0009 nm in NiTe. Accordingly, the c/a ratio decreases linearly with increasing x.

The structural similarity of CoTe and NiTe and the linear composition dependences of lattice parameters

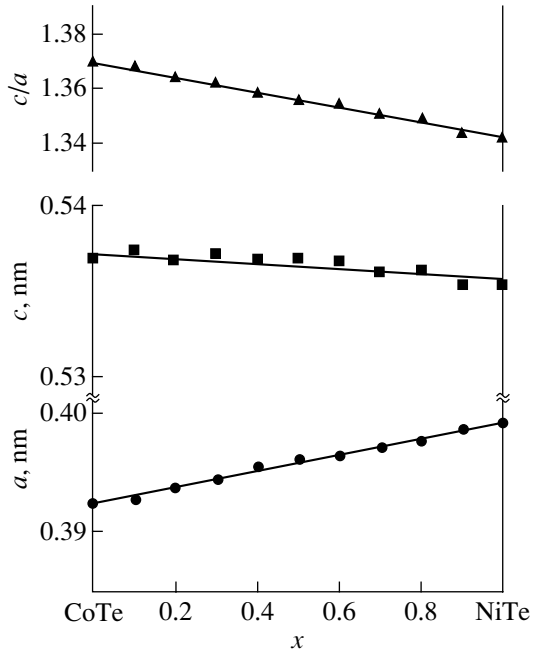

Fig. 1. Composition dependences of lattice parameters for $Co_{1-x}Ni_xTe$ alloys.

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Lattice parameters, density, and microhardness of $Co_{1-x}Ni_xTe$ alloys

x	a, nm	c, nm	c/a	$V \times 10^2$, nm^3	ρ_{meas}, g/cm^3	ρ_x, g/cm^3	H, GPa
0.0	0.3923	0.5369	1.369	7.156	8.339	8.657	5.00
0.1	0.3928	0.5375	1.368	7.182	8.326	8.624	5.30
0.2	0.3937	0.5368	1.363	7.206	8.330	8.595	5.11
0.3	0.3945	0.5372	1.362	7.240	8.313	8.553	5.07
0.4	0.3955	0.5369	1.358	7.273	8.333	8.514	5.26
0.5	0.3961	0.5369	1.355	7.295	8.323	8.487	4.93
0.6	0.3965	0.5368	1.354	7.309	8.248	8.470	4.71
0.7	0.3972	0.5361	1.350	7.325	8.288	8.450	4.49
0.8	0.3975	0.5362	1.349	7.337	8.239	8.435	4.32
0.9	0.3987	0.5353	1.343	7.369	8.199	8.397	3.74
1.0	0.3990	0.5353	1.342	7.380	8.206	8.384	3.54

indicate the formation of a continuous series of solid solutions.

Density and microhardness measurements. The density of $Co_{1-x}Ni_xTe$ was determined by the Archimedes method using carbon tetrachloride as a saturating and suspending medium [5].

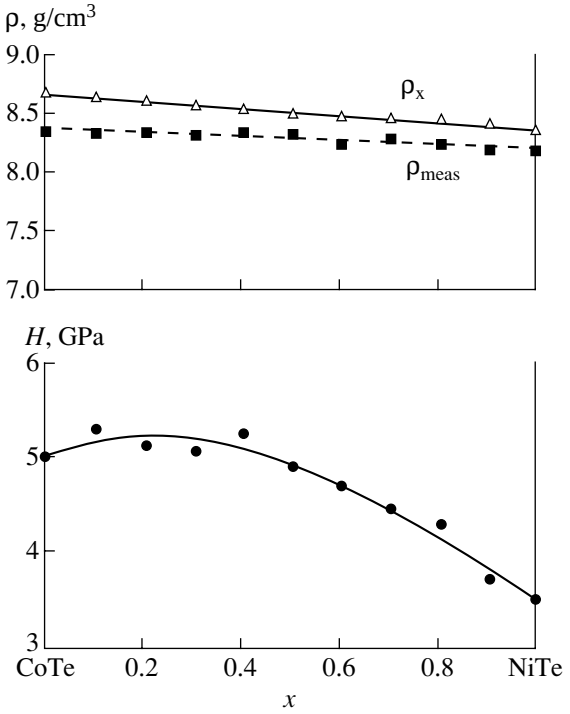

Fig. 2. Composition dependences of density and microhardness for $Co_{1-x}Ni_xTe$ alloys.

The results, together with x-ray densities, are summarized in the table and Fig. 2. The measured density of CoTe is 8.34 ± 0.05 g/cm^3 ($\rho_x \simeq 8.65$ g/cm^3), and that of NiTe is 8.20 ± 0.05 g/cm^3 ($\rho_x \simeq 8.38$ g/cm^3). Over the entire composition range, the measured density is 2–4% lower than ρ_x, which may be due to either porosity or structural imperfection. As seen in Fig. 2, the difference between ρ_{meas} and ρ_x increases with decreasing x, indicating a lower structural perfection of the CoTe-based solid solutions. The smooth variation in density is characteristic of continuous series of solid solutions.

The $Co_{1-x}Ni_xTe$ alloys were indented with a load of 0.3 N using a PMT-3 microhardness tester (table, Fig. 2). The microhardness of NiTe was 3.54 ± 0.03 GPa, and that of CoTe was 5.00 ± 0.03 GPa. The composition dependence of microhardness, $H(x)$, shows no prominent maximum, in contrast to what is typically observed for continuous series of solid solutions. This behavior seems to be due to the insignificant difference in a and c between the end-members, which leads to only small strains upon cation substitution.

CONCLUSION

X-ray diffraction studies of the samples prepared by reacting elemental mixtures in evacuated quartz tubes at 1330 K, followed by hot pressing at 7 GPa and ≃1200 K, indicate the formation of a continuous series of $Co_{1-x}Ni_xTe$ solid solutions with the NiAs structure. The resultant monolithic materials have a high strength and a density only 2–4% lower than their x-ray density. The formation of a continuous series of solid solutions is also evidenced by the composition dependences of density and microhardness.

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