Chemistry

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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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Transformations in Ternary Solid Solutions Based on Ni_3Fe

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In papers ([1–4]) the special influence of molybdenum on ordering alloys close in composition to Ni_3Fe was noted. It was found that alloying with molybdenum fundamentally changes the character of the transformation during tempering of these alloys, which is manifested in an anomaly of the electrical resistivity and in volume effects different from those of ordering. In the present work the influence of elements of different nature—Mn, Si, Cu, Mo, Cr, V, and W—on the ordering process of the Ni_3Fe alloy was studied.

Figure 1 shows the change in electrical resistivity of alloys with various alloying additions as a function of quenching temperature in the course of stepwise cooling. The initial state of all alloys was obtained after quenching from 900° into water. The duration of holding at the corresponding quenching temperature varied from 24 to 120 hours.

Alloying with Mn (3%) considerably strengthens the ordering effect observed in the unalloyed Ni_3Fe alloy and noticeably raises the temperature of the order-disorder transformation. Alloying with Cu (5%) reduces the ordering effect, acting in the same way as a deviation from the stoichiometric composition in the binary Fe–Ni alloy (for example, an alloy with 79% Ni).

Fig. 1. Change in electrical resistivity of Fe–Ni alloys alloyed with various elements as a function of quenching temperature: 1—Ni_3Fe alloy; 2—Fe–Ni (79% Ni); 3—$Ni_3(Fe, Cu)$; 4—$Ni_3(Fe, Cr)$; 5—$Ni_3(Fe, Mo)$; 6—$Ni_3(Fe, Mn)$; 7—$Ni_3(Fe, Si)$; 8—$Ni_3(Fe, W)$; 9—$Ni_3(Fe, V)$

In alloys alloyed with Mo (5%), Cr (5%), V (4%), and W (4%), after prolonged stepwise heat treatment an anomalous increase in electrical resistivity is observed; in the alloy with Cr it reaches 6.5%, in the alloy with Mo—12%, and in the alloy with V—20%. In the alloy with W the effect of increased electrical resistivity is comparatively small (2.5%). In the alloy with 3% Si, which also exhibits an anomaly of electrical resistivity, the curve has

Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

maximum at 450°. Above this temperature the electrical resistivity of the alloy with Si increases more rapidly than the electrical resistivity of the other alloys.

Figure 2 presents curves of the change in the coefficient of thermal expansion a as a function of temperature for several of the alloys studied. The initial state was obtained as a result of prolonged stepwise cooling in the temperature interval from 550 to 250°. The curves for the alloy Ni_3Fe and the alloy $Ni_3(Fe, Mn)$ (Fig. 2, a,) are characterized by the presence of a Λ-shaped maximum. A maximum of similar form was observed [5] on the temperature curves of the heat capacity of ordered specimens of the alloy Ni_3Fe during their disordering.

Fig. 2. Dependence of the coefficient of thermal expansion (a) on temperature: a—Ni_3Fe alloy; —$Ni_3(Fe, Mn)$; —$Ni_3(Fe, Cu)$; —$Ni_3(Fe, V)$.
Fig. 3. Thermomagnetic heating and cooling curves of the alloy $Ni_3(Fe, V)$; 4% V; a—after quenching from 900° in water; —after stepwise treatment; 1—heating, 2—cooling.

From comparison of these curves it is evident that the temperature of the order-disorder transformation for the alloy $Ni_3(Fe, Mn)$ is higher than for the binary alloy Ni_3Fe. The introduction of Cu causes considerable broadening of the maximum on the curve (Fig. 2,) and a lowering of the transformation temperature to 450°, which is evidently connected with concentration disordering.

The curve in Fig. 2, , was obtained for the alloy $Ni_3(Fe, V)$; however, the curves for alloys with Mo and Cr have exactly the same form. All these curves are characterized by the absence of the maximum characteristic of ordering alloys and by the presence of a discontinuity in the dependence of a on temperature. The highest temperature ($\sim 600°$) corresponding to the discontinuity was observed in the case of alloys with V, somewhat lower ($\sim 520°$) for the alloy with Mo, and still lower ($\sim 500°$) for the alloy with Cr.

Figure 3 gives thermomagnetic curves typical of alloys alloyed with one of the elements that give an anomaly of electrical resistivity (V, Mo, Cr), and Fig. 4, for comparison, gives thermomagnetic curves of ordering alloys Ni_3Fe and $Ni_3(Fe, Mn)$.

The thermomagnetic curves of alloys exhibiting an anomaly of electrical resistivity and an anomalous temperature dependence of the coefficient of thermal expansion are similar and are characterized by a diffuse magnetic transformation on heating and cooling. The latter can be explained by local chemical inhomogeneity of the solid solution. Apparently, in the solid solution, at certain temperatures, around impurity atoms

because, owing to the manifestation of chemical affinity to the atoms of the principal components of the solid solution, chemical complexes are formed which

Fig. 4. Thermomagnetic heating and cooling curves: a –alloy Ni3Fe; b –Ni3(Fe, Mn); 3% Mn; 1 –after quenching from 900° in water; 2 –after stepwise heat treatment

Figure 3: Fig. 4. Thermomagnetic heating and cooling curves: a –alloy Ni3Fe; b –Ni3(Fe, Mn); 3% Mn; 1 –after quenching from 900° in water; 2 –after stepwise heat treatment

are distinguished by a higher Curie point. This is confirmed by the fact that the Curie point of the quenched alloy is considerably lower than the Curie point of the alloy subjected to prolonged stepwise cooling (see Fig. 3). In all cases the Curie point of the quenched specimen on cooling is considerably higher than on heating (Fig. 3a). This indicates that the rate of formation of these complexes during cooling is greater than the rate of ordering of the alloy Ni_3Fe.

The more the alloying element, by its nature, differs from the principal elements forming the solid solution–from iron and nickel–the stronger is the chemical affinity and the more stable are the complexes formed in the solid solution. This supposition can be confirmed by the stronger influence of V, as compared with Cr and even Mo.

Fig. 4. Thermomagnetic heating and cooling curves:
a –alloy Ni_3Fe; *b* –$Ni_3(Fe, Mn)$; 3% Mn; 1 –after quenching from 900° in water; 2 –after stepwise heat treatment

The peculiar influence of Mn is evidently connected with the fact that in the ordered solid solution Mn, possessing an incomplete 3*d* shell, takes part in the magnetic interaction. In the ordered state the magnetic saturation of the alloy $Ni_3(Fe, Mn)$ is considerably greater than that of the alloy Ni_3Fe, whereas after quenching Mn, like the other elements, lowers the magnetic saturation of the alloy Ni_3Fe (Fig. 4). The additional decrease in electrical resistance on tempering is for this reason connected with the increase in magnetic saturation upon ordering of the alloy $Ni_3(Fe, Mn)$.

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