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PRESSURE EFFECT ON CURIE TEMPERATURE FOR \((\text{FeNi})_{90}\text{Zr}_{10}\) AMORPHOUS ALLOYS

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Abstract. — Pressure effect on Curie temperature, \(dT_c/ dp\), for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys is estimated indirectly from forced volume magnetostriction. The alloys change from magnetically heterogeneous state to homogeneous one in Fe-rich region with increasing Ni, and stay in homogeneous one even in Ni-rich region differently from the results of \(dT_c/ dp\) measured directly.

1. Introduction

Magnetic properties for \(\text{Fe}_{90}\text{Zr}_{10}\) based amorphous alloys have been investigated recently, because they show Invar effect [1]. In this paper, pressure effect on Curie temperature \(T_c\), \(dT_c/ dp\), for amorphous \((\text{Fe}_{1-x}\text{Ni}_x)_{90}\text{Zr}_{10}\) alloys is estimated indirectly from measurements of forced volume magnetostriction \(\omega_v/ dH\) using the Kornetzki-Kouvel's relation [2], and is compared with the results of \(dT_c/ dp\) measured directly [3]. Those measured directly show that absolute values of \(dT_c/ dp\) decrease monotonically with increasing Ni. This suggests that according to the Wagner-Wohlfarth's discussion [4] these amorphous alloys change from homogeneous state to heterogeneous one.

However, it may be thought that the concentration dependence of \(dT_c/ dp\) has the extreme value around \(x = 0.1\) of Ni, because concentration dependences of magnetic moment \(n\) [1] and spontaneous volume magnetostriction \(\omega_v(0)\) obtained from the results of thermal expansion [1] have the maximum values around \(x = 0.1\) of Ni like as those for amorphous \((\text{FeCo})_{90}\text{Zr}_{10}\) alloys [1]. Therefore, it is expected that amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys change from heterogeneous state to homogeneous one around \(x = 0.1\) of Ni like as amorphous \((\text{FeCo})_{90}\text{Zr}_{10}\) alloys [5] in contrast to the results of \(dT_c/ dp\) measured directly [3]. To ensure that, estimating \(dT_c/ dp\) for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys should be done in the whole range of Ni.

2. Experiments

Specimens prepared by the single-roller quenching technique were amorphous \((\text{Fe}_{1-x}\text{Ni}_x)_{90}\text{Zr}_{10}\) \((0 \leq x \leq 0.9)\) and in the form of ribbons 1-2 mm wide. Ribbons 22 mm long were used as samples. Measurements of \(\omega_v/ dH\) were done by the three-terminal capacitance method [6] in fields up to 18 kOe and at temperatures from 4.2 K to \(T_c\).

3. Results and discussion

In figure 1, magnetic moment per 3d transition metal \(n\), \(T_c\) and crystallization temperature \(T_{cry}\) for amorphous \((\text{Fe}_{1-x}\text{Ni}_x)_{90}\text{Zr}_{10}\) alloys are shown as a function of Ni content \(x\), together with the results published [3]. Magnetic moment \(n\) shows the maximum around \(x = 0.1-0.2\). Curie temperatures \(T_c\) are below \(T_{cry}\) in the whole range of Ni content. The results of \(n\), \(T_c\) and \(T_{cry}\) agree well with the results of reference [3].

Fig. 1. — Magnetic moment per 3d transition metal \(n\), \(T_c\) and \(T_{cry}\) vs. Ni content \(x\) for amorphous \((\text{Fe}_{1-x}\text{Ni}_x)_{90}\text{Zr}_{10}\) alloys, together with the results published [3].
In figure 2, temperature dependences of \( \frac{d\omega}{dH} \) for amorphous \((\text{Fel}-x\text{Ni})_{90}\text{Zr}_{10}\) alloys are shown. The values of \( \frac{d\omega}{dH} \) decrease with increasing Ni. The sharp peak is seen at \( T_c \) in Fe-rich region, but the broad minimum in Ni-rich region. From these results, pressure effects on magnetic moment per gram \( \sigma_0 \) at \( 0 \) K, \( \frac{d\ln \sigma_0}{dp} \), and on \( T_c \), \( \frac{dT_c}{dp} \), can be estimated indirectly using the Kornetzki-Kouvel's relation [2]:

\[
\frac{d\omega}{dH} = -\rho \left( \frac{d\sigma_0}{dp} \right)
\]

and \( \frac{d\omega}{dH} = \rho \sigma_s \left[ T \frac{d\ln \sigma_s}{dT} \right] \left( \frac{d\ln T_c}{dp} \right) - \frac{d\ln \sigma_0}{dp} \).

In this paper, only \( \frac{dT_c}{dp} \) is described, and \( \frac{d\ln \sigma_0}{dp} \) will be done elsewhere.

In figure 3, the results of \( \frac{dT_c}{dp} \) estimated indirectly for amorphous \((\text{Fel}-x\text{Ni})_{90}\text{Zr}_{10}\) alloys are shown as a function of \( T_c \), together with those measured directly for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) [3] and crystalline FeNi alloys [7]. The values of \( \frac{dT_c}{dp} \) estimated indirectly for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys take the minimum around \( x = 0.1 \) of Ni and change the sign from negative to positive with increasing Ni. This behavior of \( \frac{dT_c}{dp} \) estimated indirectly is the same as that for amorphous \((\text{FeCo})_{90}\text{Zr}_{10}\) alloys [5] in Fe-rich region and as that for crystalline FeNi alloys [7] in Ni-rich region in contrast to the results of \( \frac{dT_c}{dp} \) measured directly for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys [3].

According to the Wagner-Wohlfarth’s discussion [4], \( \frac{dT_c}{dp} \) are expressed as \( \frac{dT_c}{dp} = -aT_c + bT_c^2 \) for magnetically heterogeneous state and as \( \frac{dT_c}{dp} = aT_c - b/T_c \) for homogeneous one from Landau-Ginzburg model. The behavior of \( \frac{dT_c}{dp} \) estimated indirectly for amorphous \((\text{FeNi})_{90}\text{Zr}_{10}\) alloys shows to change from magnetically heterogeneous state to homogeneous one around \( x = 0.1 \) of Ni and to stay in homogeneous state even in Ni-rich region. This is contrast to that measured directly which shows to be magnetically homogeneous state in Fe-rich region and to change to heterogeneous one in Ni-rich region [3].

To check the heterogeneity in details, Mössbauer effect is necessary to be applied.