INVAR BEHAVIOR AND THERMOELASTIC MARTENSITIC TRANSFORMATION OF AN Fe-22.5 at. % Pt ALLOY
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Abstract.- In an Fe-rich Fe-Pt alloy it is shown that the martensitic transformation is thermoelastic even when the volume change induced by the transformation is large.

The martensitic transformation in Fe-Pt alloys near the composition Fe₃Pt is unique in that the character of the transformation changes from a burst-like one to a thermoelastic one as the degree of order increases [1, 2, 4]. On the other hand, Fe-Pt alloys are known to exhibit a strong invar effect [6] in the γ-phase which reduces the volume change associated with the transformation.

For Fe-Pt alloys in the composition range 24-25 at.% Pt Tadaki and Shimizu [1, 2] observed Mₐ, for well ordered specimens. For such alloys the magnetically induced volume expansion in the γ-phase is large enough to make the volume of the γ-phase approximately equal to that of the α-phase. Based on this experimental result Tadaki and Shimizu concluded that a small volume change at the transformation temperature is essential for the transformation in Fe-Pt alloys to be thermoelastic.

We have investigated an Fe-Pt alloy having a low platinum content. For such an alloy, in its ordered state ΔV₁-γ is not or at least weakly modified by the invar effect. The purpose of this investigation is to check whether the transformations for such an alloy is thermoelastic or not.

We have prepared an Fe-Pt alloy containing 22.5 at.% Pt. The disordered state was obtained by annealing the alloy at 1150°C for 6 h in vacuum followed by water quenching. The fully ordered state was obtained by a heat treatment at 600°C for 2 weeks and at 550°C for another 2 weeks. We monitored the martensitic transformation in both the disordered and ordered states by measuring the thermal expansion, Δl/l, and the magnetization intensity, M. The results are shown in Fig. 1.

The transformation temperatures taken from Fig. 1 are listed in Table 1 together with the Curie temperature which was identified as the maximum of the specific heat curve measured by differential scanning calorimetry.
Table I: Transformation temperatures (°C) of Fe-22.5 at.%M Pt alloy

<table>
<thead>
<tr>
<th></th>
<th>T_c</th>
<th>M_s</th>
<th>M_f</th>
<th>A_s</th>
<th>A_f</th>
</tr>
</thead>
<tbody>
<tr>
<td>disordered</td>
<td>-</td>
<td>25</td>
<td>-</td>
<td>470</td>
<td>500</td>
</tr>
<tr>
<td>ordered</td>
<td>42</td>
<td>-55</td>
<td>-125</td>
<td>-75</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 1 shows that the ordered Fe-22.5 at.% Pt alloy still shows an invar effect below T_c. Since T_c-M_s and the magnitude of the invar effect itself is much smaller compared with alloys near Fe-Pt, \(\Delta V^{\gamma-\alpha'}\), is reduced insignificantly by the invar effect. From Fig. 1 we obtain \(\Delta V^{\gamma-\alpha'} = 1.3\%\) at M_s for the ordered state and \(\Delta V^{\gamma-\alpha'} = 2\%\) for the disordered state. These values are in good agreement with the results of Umemoto and Wayman [4] who measured, below M_s, the lattice parameters of the \(\alpha'\) and \(\gamma\)-phases, respectively.

For the ordered Fe-22.5 at.% Pt alloy the character of the transformation remains thermoelastic even when \(\Delta V^{\gamma-\alpha'}\) is large. The thermoelastic transformation is evidenced i) by the fact that the ordered alloy exhibits the shape memory effect and ii) by a small hysteresis. If we characterize the hysteresis by the half width, \(\omega\), of the transformation cycle, i.e., at 50 % transformation, we get from Fig. 1 \(\omega = 75°C\) for the ordered state and \(\omega = 500°C\) for the disordered state.

This result shows that a small \(\Delta V^{\gamma-\alpha'}\) is not a necessary condition for the occurrence of a thermoelastic transformation in Fe-Pt alloys. This correlates with observations on other alloys reported by Magee and Davies [5] who found in a series of Fe-Ni-Co alloys that the transformation remained nonthermoelastic in these alloys even when \(\Delta V^{\gamma-\alpha'}\) was zero. Other factors, as proposed by Christian [7], such as a small chemical driving force and a high flow stress of the matrix appear to be much more important in controlling the thermoelastic transformation.

References

Fig. 1: Forward and reverse transformation of Fe-22.5 at.% Pt alloy (—ordered, ----disordered) followed by the measurement of magnetization intensity (upper curve) and of the thermal expansion (lower curve).