A STUDY OF SHAPE MEMORY EFFECT ABOVE M_s TEMPERATURE IN A Cu-Zn ALLOY USING THE TWISTING DEFORMATION AND ELECTRIC RESISTANCE METHODS

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INTRODUCTION

The shape memory effect (SME) is generally recognized to be caused by the reverse transformation of the deformed thermoelastic martensite (TEM); in a TiNi alloy, however, it has been reported that the SME is not related to the thermoelastic martensite but is caused by stress--induced martensite (SIM) [1]. The SME is mainly related to the R-phase transformation [2].

In a CuZn alloy, the SME is still thought to be caused by the reverse phase transformation of the deformed TEM [3]. K. Otsuka et.al reported that the SME in CuZn alloy essentially occurred between A_s and A_f, thus the electric resistance did not change by deformation, and that the heating curves of electric resistance were indistingishable for both the deformed and the undeformed specimen [4]. Because the TiNi alloy has a complicated phase transformation and the study of SME is very difficult, we chose to study a CuZn alloy which has a relatively simple phase transformation in this experiment. The study of SME has used a bending method; in this work we used the twisting method and the electric resistance R was measured simultaneously [5].

EXPERIMENTS

Two wire specimens (Sample #1 Cu-40.5wt% Zn; Sample #2 Cu-40.2Wt% Zn) with a length of 10 cm and a cross diameter of about 1 mm were held at a temperature of 1073 K for 15 min. and then quenched into ice water. The phase transformation temperature was measured by electric resistance method. The results are M_s = 128°K for sample #1, and M_f = 135°K, A_f = 226°K for sample #2. Sample #1 was cooled from room temperature to 135°K which is 7°K above M_s (= 128°K), the temperature was then kept constant while the twisting angle ($\Delta\phi$) plastically developed and, at the same time the electric resistance R was measured. Then the sample was heated, and the shape recovery ($\Delta\phi$) and the relative resistance R were measured. Sample #2 was cooled from room temperature to 120°K which is below the M_f (= 135°K), then kept the temperature constant, and was made twisting angle ($\Delta\phi$) plastically, at same time measured the relative resistance R. Then the sample #2 was heated, and the shape recovery ($\Delta\phi$) and relative resistance R was measured.

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RESULTS AND DISCUSSION

The SME in Cu-Zn alloy above the M_s

The results for sample #1 are shown in Fig. 1. On cooling, the curve 1 is a straight line, so that the TEM transformation has not occurred. At a constant temperature of 135°K (=M_s+7K) it was twisted plastically and this result is shown in Fig. 1 as line 4. It is also shown in Fig. 2 that the curve R vs. twisting angle $\Delta\phi$ has a shape like a step. The increase of R can only be explained by a phase transformation that is induced by the twisting deformation. Since the sample was twisted at 7°K above M_s (below M_d), and since under stress only SIM transformation (P→M) has been found, Fig. 2 shows that the curve shape like a step means that the martensite induced by stress is not uniform. In Fig. 1 curve 2 the small protruding part corresponds to the fast shape recovery. The reason for this phenomenon is not clear. From curve 3, sample #1 shows that the total recovering SME ratio is 94%; we are thus sure that the SME is caused by the reverse transformation of SIM and not by the TEM.

The SME in Cu-Zn alloy below M_s

The measurement result of SME and resistance R of sample #2 (Cu-40.2wt% Zn) is shown in Fig. 3. It was twisted at 120°K which is below the M_f; its R-$\Delta\phi$ curve has the shape of a step, as shown in Fig. 4. Figure 3 in which the resistance R peaks appear, shows that the TEM

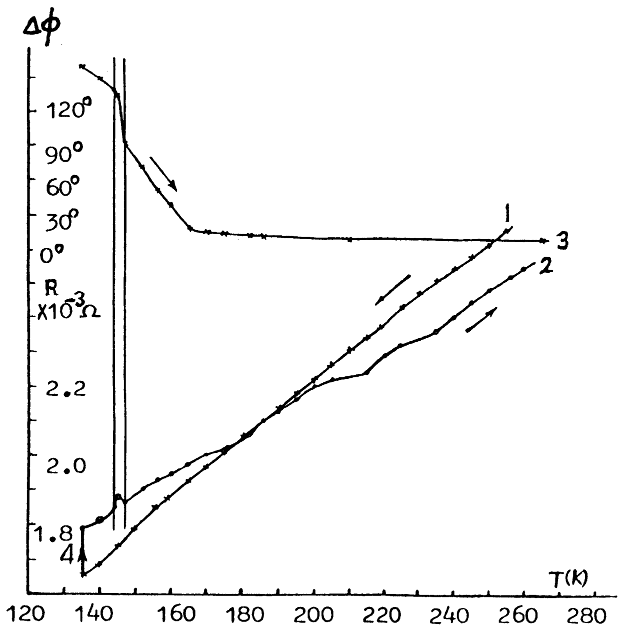

Fig. 1. The electric resistance change in Cu-Zn sample #1 (Cu-40.5wt% Zn) during SME above M_s. Curve 1: The resistance R vs. temperature T on cooling; Curve 2: The R-T curve on heating; Curve 3: The shape recovery on heating, the total recovering ratio is 94%; Curve 4: The sample was twisted plastically at constant temperature 135 K (= M_s + 7K).

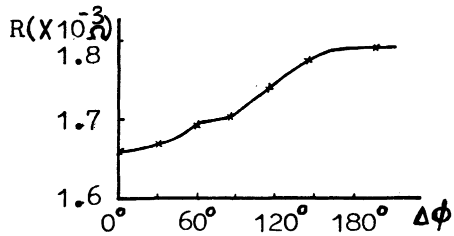

Fig. 2. The resistance R vs. twisting angle $\Delta\phi$ of sample #1 which was plastically twisted at 135K (= M_s+7K). This curve is line 4 in Fig. 1.

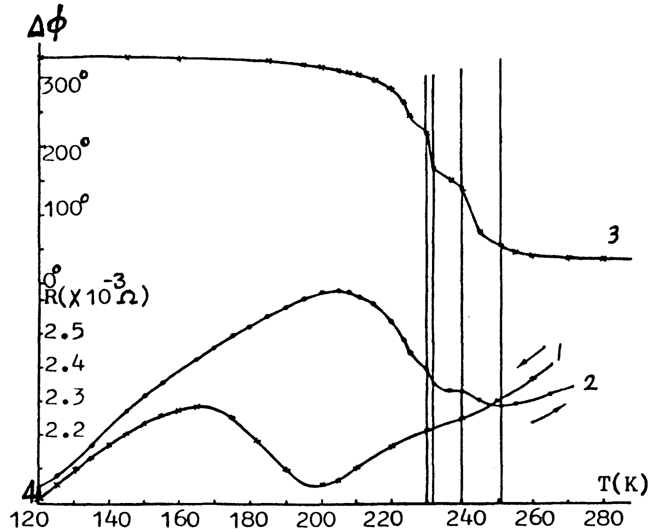

Fig. 3. The shape recovery and resistance change during SME in Cu-Zn sample #2 (Cu-40.2wt% Zn). Curve 1: The electric resistance R vs. temperature T on cooling; Curve 2: The R-T curve on heating; Curve 3: The shape recovery on heating, the total recovering ratio is 92%; Curve 4: The sample was twisted plastically at constant temperature 120K which is below the M_f

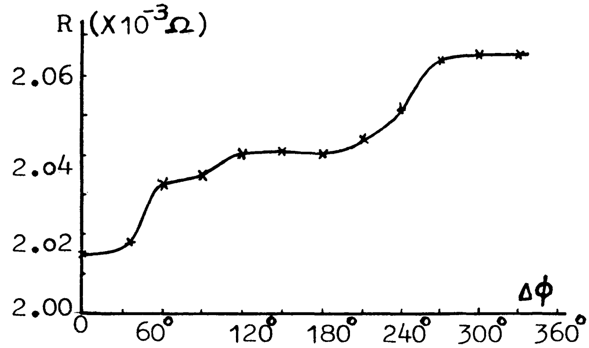

Fig. 4. The resistance R vs. twisting angle Δϕ of sample #2 which was plastically twisted at 120K. This curve is line 4 in Fig. 3.

transformation was occurred. From Fig. 4, the curve like a step shows that this transformatioh is not uniform. This increase of R can be explained by the SIM, and is not due to the reorientation of TEM or twinning. Because the change of R is proportional to the amount of TEM [6], and the reorientation of TEM or twin cannot be increased, the SIM should be transformed from the TEM. This means the increase of R induced per degree in Fig. 4 is much smaller than that is in Fig. 2. The strong internal stress existing in the sample below M_f makes the SIM induced by external stress more difficult.

In Fig. 3 curve 2, there are two protruding parts at the temperature 230° and 240°K that have the character of a reverse SIM transformation. The two protruding parts correspond to two temperatures at which the shape recovery is fast. This result is the same as in Fig. 1 curve 2 and 3 at temperature 145K. In Fig. 3, from 230K to 251 K, the shape recovery is 65%. Thus, the SME is mainly caused by SIM. This point of view must be studied by other methods.

CONCLUSION

The TEM is not the necessary condition of the SME. In a Cu-Zn alloy, when the temperature is above M_s, the SME is caused entirely by the SIM.

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