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ACOUSTIC EMISSION DURING MARTENSITIC TRANSFORMATION IN THE β Cu-Zn ALLOY

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The double martensitic transformation in the β_1 Cu-Zn alloy was studied using dilatation measurement and acoustic emission (AE) analysis represented by root mean square (rms) voltage and ring-down counting. The slowly growing banded martensite is distinguished by dilatometric changes and very low amplitude, high repetition rate acoustic emission. The burst type martensite is completely self-accommodated, accompanied by high amplitude, low repetition rate emission bursts. The effect of thermal cycling on both the number of ring-down counts and the apparent martensitic start and end temperatures is discussed.

1. Introduction

On cooling the β_1 Cu-Zn alloy two types of martensite appear$^{1)}$: first, at a high subzero temperature, a monoclinic lattice β_1 than at a lower temperature a triclinic lattice β_1. The first type corresponds to the banded, slowly growing martensite, while the second corresponds to the parallelogram-shaped, abruptly forming martensite noticed by Pops and Massalski$^{2)}$. These transformations were studied by Pascual et al.$^{3)}$ for single crystals. Their experiments showed that AE is mainly due to the first type martensite while no AE was found during the formation of the second type.

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The aim of the present work is to extend the study to the martensitic transformation in the polycrystalline β Cu-Zn alloy using dilatometric measurement and AE analysis. Our preliminary experiments have shown that two different types of signals contribute to AE; the first resembling low amplitude continuous AE and the second contributing to discrete AE of the burst type. Therefore two different techniques need to be applied for the study od the AE. We have applied rms measurement and ring-down counting techniques.

From the experimental results obtained and the properties of successive martensitic transformations a plausible explanation of the characteristics of the complete phenomenon is then put forward.

2. *Experimental procedure*

A diagram of the experimental system is given in Fig. 1. The Cu-39.6% Zn specimens were prepared by the same technique as described by Pops and Massalski. They were 3 cm long cylinders of diameter 6 mm and diffusion welded to a 20 cm long stainless steel waveguide[4]. The AE signals were transmitted along the waveguide to a *PZT* (lead zirconate titanate) transducer of resonant frequency 200 kHz and sensitivity —80 db rel. 1V/μb. The signals from the transducer were amplified 20.000 times by a preamplifier and amplifier. Oscillations of amplitude higher than 1 V were counted and the total number (N) and the rate ($\dot{N}$), were recorded to a temperature base, while the root mean square voltage of AE bursts (V) and the temperature (T) were plotted as functions of time. The specimen and waveguide were inserted into a silica tube and immersed in liquid nitrogen to be cooled and then taken out to be heated in air. The dilatometric changes were measured separately on the same specimen and recorded as a function of temperature.

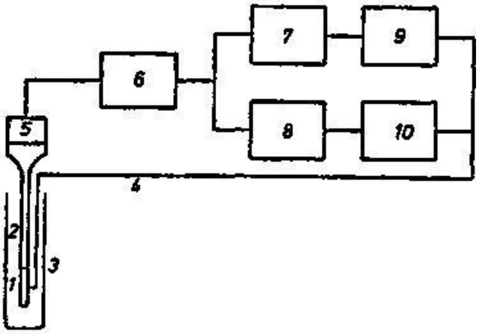

Fig. 1. Diagram of the experimental system.

1 — Specimen
2 — Wave guide
3 — Silica tube
4 — Thermocouple
5 — PZT transducer
6 — Preamplifier and amplifier
7 — RMS voltmeter
8 — Ratemeter and counter
9 — TY_1Y_2 recorder
10 — XY_1Y_2 recorder.

3. Results

The record of the dilatometric changes represented in Fig. 2 shows that the transformation starts at —75 °C (M_s) and ends at —128 °C (M_F) on cooling, while the reverse transformation occurs between —107 °C (A_s) and —65 °C (A_F).

The rms voltage of the AE bursts shows the corresponding temperature intervals from —75 °C to —145 °C and from —107 °C to —52 °C on cooling (Fig. 3) and heating (Fig. 4), respectively.

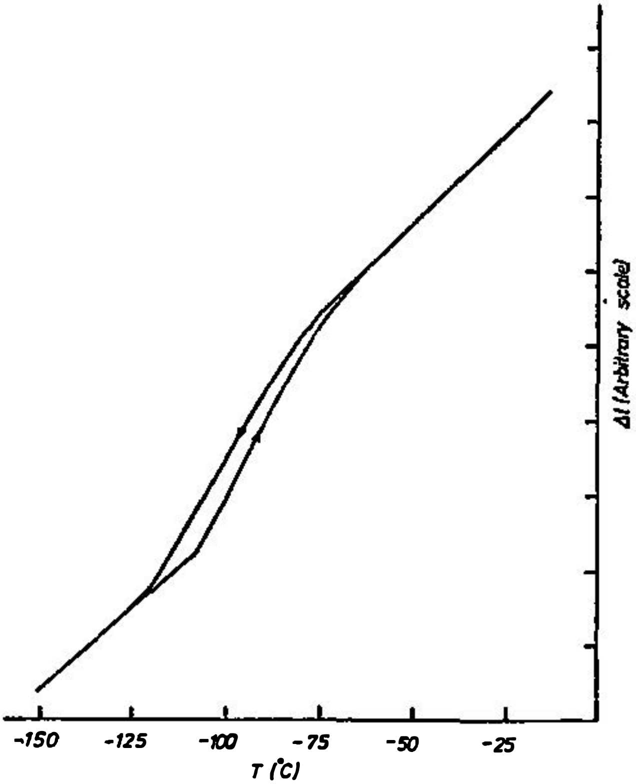

Fig. 2. Dilatometric changes on cooling and heating versus temperature.

The number and the rate of ring-down counting on heating and cooling were decreased by thermal cycling. The number of counts is given in Table 1 for the first five thermal cycles on cooling and heating while Figs. 5 and 6 show the results during the fifth cycle.

TABLE 1.

Cycle number		1	2	3	4	5
N (10^5 count)	cooling	2.9	1.7	1.5	1.2	1.0
	heating	33	31.7	30.5	29.1	28.1

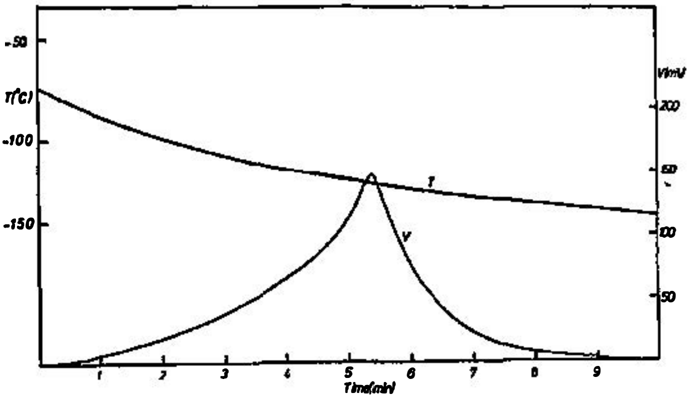

Fig. 3. Root mean square voltage and temperature versus time on cooling.

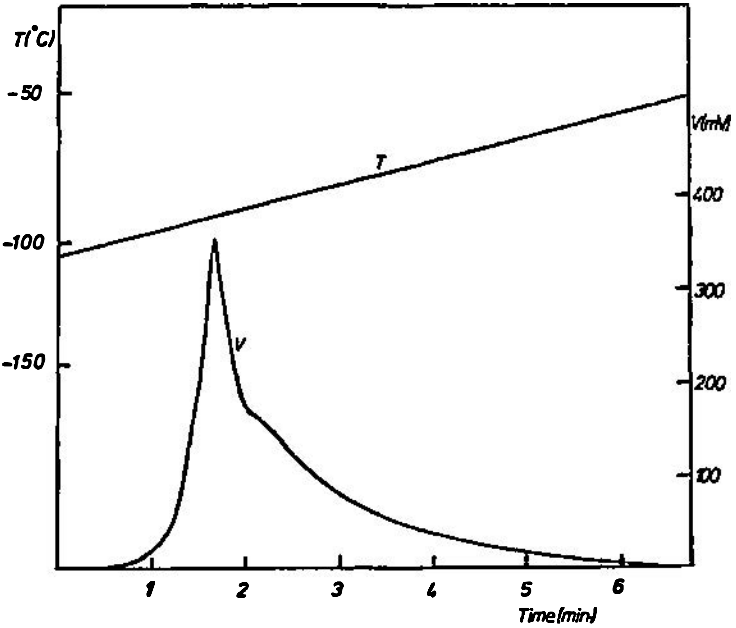

Fig. 4. Root mean square voltage and temperature versus time on heating.

The martensitic start and end temperatures obtained from Fig. 5 are —115 °C and —135 °C while the corresponding temperatures in the reverse transformation are —94 °C and —65 °C, Fig. 6.

For a comparison between the different measuring techniques the above results are summarized in Table 2.

TABLE 2.

Technique	RMS voltage	Dilatation	Ring-down counting (cycle 5)
M_S	−75	−75	−115
M_F	−145	−128	−135
A_S	−107	−107	−94
A_F	−52	−65	−65

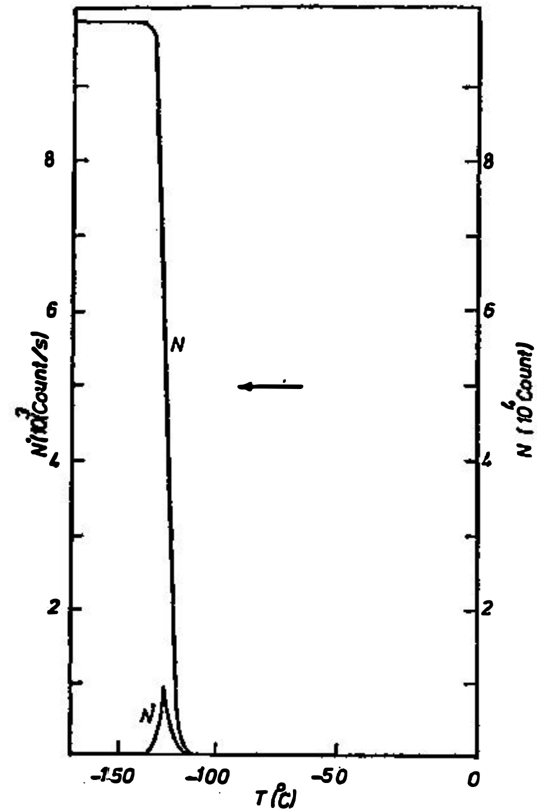

Fig. 5. Ring-down counting, total number and rate versus temperature on cooling.

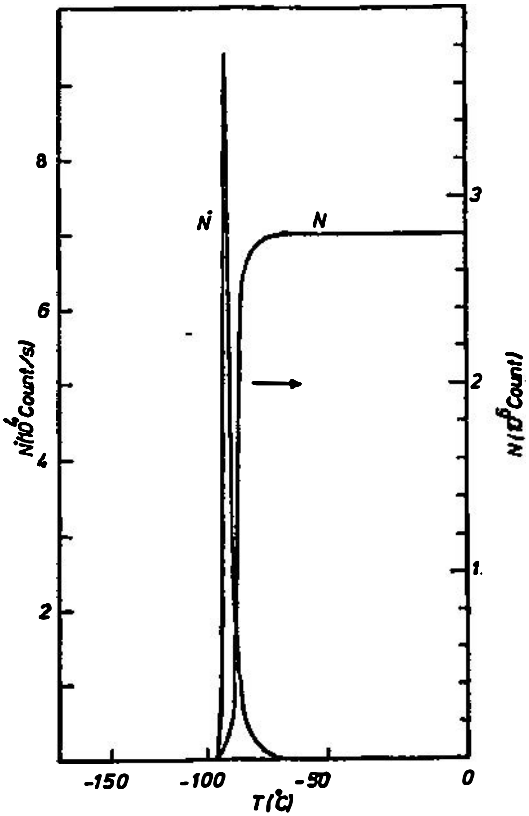

Fig. 6. Ring-down counting, total number and rate versus temperature on heating.

4. Discussion

On cooling, AE signals start growing at —75 °C and continue up to —145 °C, as seen from the rms voltage curve in Fig. 3. Ring-down counting occurs between —115 °C and —135 °C. Of course these are the signals of amplitudes higher than 1 V while the lower amplitude signals are not counted. No abrupt increase is seen in the rms voltage curve corresponding to the start of ring-down counting at —115 °C. This shows that the low amplitude signals between —75 °C and —115 °C are of higher repetition rate while the higher amplitude signals from —115 °C to —135 °C are of lower repetition rate.

The low amplitude, high repetition rate bursts correspond to the slowly growing banded martensite while the high amplitude bursts are due to the parallelogram shaped, abruptly formed, martensite$^{2)}$. The lower amplitude AE between —135 °C and —145 °C is due to a very low transformation rate or stress relaxation following the end of the martensitic transformation.

It is seen from the dilatometric measurement and the AE on cooling that the dilatometric changes are mainly due to the formation of the banded martensite since the maxima of the ring-down counting rate and the rms voltage at the end of the dilatometric changes are at −128 °C. This shows that the burst type martensite is completely self-accommodated.

On heating, the AE starts at −107 °C and ends at −52 °C and is higher than that on cooling. The maximum rms voltage is approximately twice while the number of ring-down counts is much higher. The rms plot shows a rapid increase and abrupt decrease following the maximum, due to the reverse transformation of the burst martensite, followed by a slower decrease from −83 °C to −52 °C.

The dilatometric changes and the AE records on heating show that both types of martensite start retransforming together at −107 °C since the burst type of martensite is not responsible for dilatometric changes. The very weak AE between −65 °C and −52 °C might also be due to stress relaxation following the end of transformation.

The dilatometric changes clearly show the start and end of the transformation of the banded martensite, which were not well defined by the resistivity measurement done by Pascual et al.[3] and by Hummel and Koger[5].

Using both rms and ring-down counting enabled us to detect both types of AE and to indicate their origin. The rms voltage curve starts rising from the background noise at a very low level while the ring-down counting occurs for burst amplitudes higher than a pre-set trigger level of 1 V.

Attention should be paid to the changes in the apparent start and end temperatures measured by the ring-down counting technique. The total number of ring-down counts and the amplitude of the AE bursts are decreased by thermal cycling; this causes a later start and shorter duration of counting, which means a lower martensitic start and higher martensitic finish temperatures. Similarly in the reverse transformation, the thermal cycling causes an increase in the β start and a decrease in the β finish temperatures.

5. *Conclusion*

The study of martensitic transformation in the β Cu-Zn alloy by simultaneous dilatometric, rms voltage and ring-down counting shows that the β_1' martensitic transformation is accompanied by high dilatometric changes and low amplitude, high repetition rate AE bursts. The corresponding signals resemble the continuous type of AE and were therefore characterized mainly by rms voltage. Contrary to this the β_1 martensitic transformation is completely self-accommodated. It is accompanied by high amplitude, low repetition rate bursts resembling typical discrete AE which can be characterized by ring-down counting.

Due to thermal cycling of the specimen, the total number of ring-down counts is decreased and changes in the martensitic start and finish temperatures are found.

Research is in progress to measure the released forces and amplitude distribution in order to obtain more exhaustive data about these transformations.

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AKUSTIČNA EMISIJA MED FAZNO PREMENO V β Cu-Zn ZLITINI

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V članku je opisana študija dvojne martenzitne premene v β_1 CuZn zlitini, ki je bila izvedena z merjenjem raztezanja in z analizo akustične emisije na osnovi merjenja efektivne napetosti ter štetjem iznihavanja. Za pošasi rastoči trakasti martenzit je značilno raztezanje in akustična emisija v pogostih izbrubih nizkih amplitud. Za hitrorastoči notranje usklajeni martenzit pa so značilni močni akustični izbruhi z nizko pogostostjo. Opisan je vpliv termičnega cikliranja na akustično iznihavanje ter navidezni temperaturi začetka in konca martenzitne premene.