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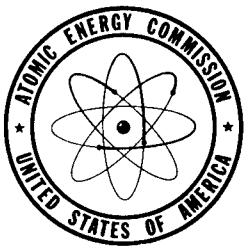

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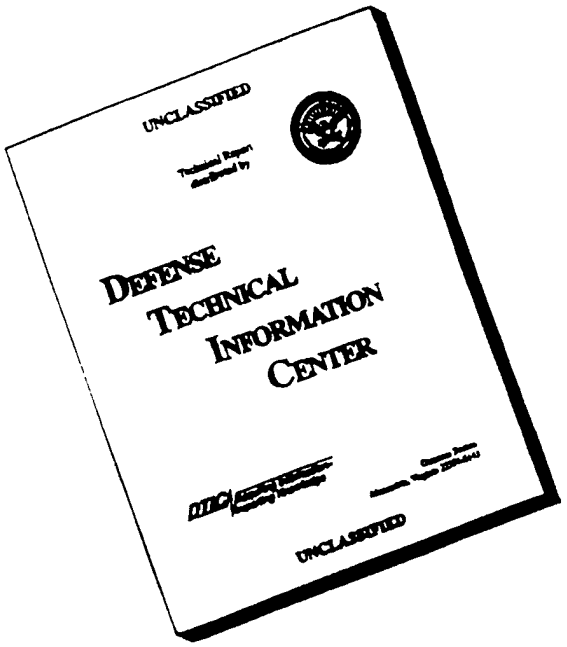

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Effect of Plastic Deformation on Subsequent Decomposition in Aluminum Alloys Al-Si and Al-Mg-Si

N. N. Buinov and V. P. Savinykh

The effect of plastic deformation on subsequent decomposition in the alloys Al-Si (1.2 percent Si) and Al-Mg-Si (1.4 percent Mg_2Si) was studied with an electron microscope. These alloys were chosen because the first is easily quenched and does not age at room temperature and because in the second no decomposition after quenching and natural aging is detected with the electron microscope (although the properties change). These alloys were chosen also because they could be studied by the oxide-film method. This method was used to study the surface of the samples, which was etched before deformation and aging. It is then possible to observe simultaneously, on the electron photographs, precipitation, the block structure, and those alterations (slip lines, bending of blocks, cracks, etc.) in the submicroscopic structure of the alloys which are caused by deformation.

The samples of the alloys, which were in the form of bars 4.5 by 4.5 by 15 mm and rods 2 by 2 by 50 mm after annealing at 530°, were quenched and then etched. After this operation, the bars were subjected to compression and the rods to extension, ranging from a few percent to 20 percent. The deformation was determined by the change in length of the samples.

The samples were then aged in the temperature range from 100° to 260°. The time of aging varied from 20 minutes to several hours. In most of the experiments the temperature and the time of aging were selected so as to obtain a hardness of the samples corresponding to a rising portion of the curve hardness *versus* tempering time at a given temperature. After heat treatment the oxide films were removed from the samples and examined with an electron microscope.

The effect of plastic deformation on decomposition is illustrated by the photographs in Figs. 1 to 3.

The photograph in Fig. 1 was obtained from the alloy Al-Si which had been tempered at a temperature of 210° for 1 hour and 40 minutes. The photograph in Fig. 2 was obtained from the same alloy, tempered at the same temperature and for the same length of time but previously deformed by a 10 percent compression. The photograph in Fig. 3 was obtained from Al-Mg-Si, tempered at 200° for 1 hour after preliminary deformation by an 18 percent extension.

The study of the alloy Al-Si showed that plastic deformation accelerated decomposition. There were 2 to 3 times as many precipitated particles for the deformed samples as for the nondeformed. In the deformed samples the decomposition was more even, throughout the individual crystallites as well as over the entire surface of the sample. The size of the particles in the deformed and nondeformed samples was about the same. In many experiments the particles in the nondeformed samples were even a little larger than in

the deformed ones.

In the alloy Al-Mg-Si no significant effect of plastic deformation on decomposition, such as an increase in the number of precipitated particles, was observed.

Analysis of a large number of electron photographs of Al-Si and Al-Mg-Si alloys subjected to heat treatment at different temperatures and for different lengths of time indicated that no preferential decomposition was observed in the zones of the traces of slipping, which are quite visible in the photographs. Preferential decomposition in the zones of the traces of

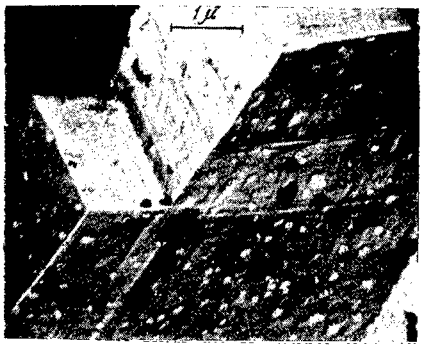

Fig. 1.

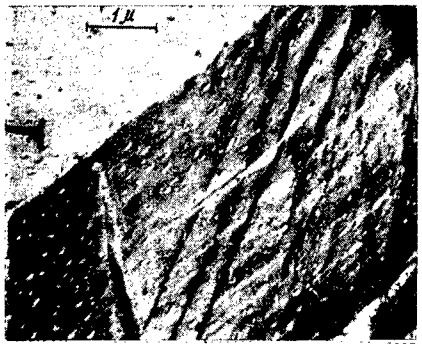

Fig. 2.

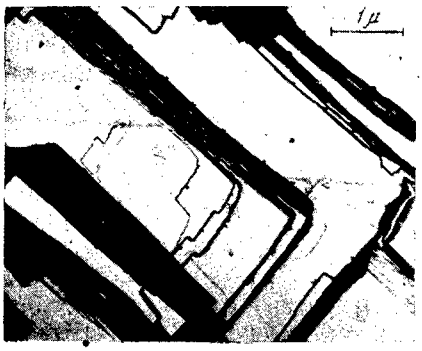

Fig. 3.

Fig. 4.

slipping was not observed in the case of slight deformations (4 percent) or in the case when oxide films were removed from the neck region of a stretched Al-Si sample which, after deformation, had been tempered at 160° for 8 hours (see Fig. 4). This fact is worthy of note since it is usually considered that decomposition after preliminary deformation takes place in the zones of the traces of slipping.

That decomposition is not preferentially localized in the neighborhood of the traces of slipping may be accounted for by the fact that the residual stresses are localized throughout the sample and not only in the traces of slipping. The concept of the distribution of the residual stresses throughout the deformed material agrees with the quantitative research of Kurnosov, Tronina, and Yakutovich.[1] These writers studied the distribution of plastic deformation by slipping throughout a crystal of zinc and showed that, for a 4 percent deformation at room temperature, only 10 percent of the deformation was localized in the visible traces of slipping, while the remaining

90 percent was distributed throughout that part of the sample which was free of traces of slipping. However, these experiments do not give us any idea of the distribution of the residual stresses, for this distribution may differ from the distribution of deformation.

The fact that decomposition is not preferentially localized in the neighborhood of the traces of slipping may be explained differently. Many investigators regard as possible a local heating of a deformed metal in the zones of the traces of slipping. Thus, for instance, Davidenkov and Terminasov,[2] in their x-ray work on deformation by static and dynamic compression of steel, account for the lesser diffusion of the K_α-doublet in the second case by a local temperature increase along the slip planes, which results in the phenomenon of relaxation and the decrease of residual stresses of the second type.

In a study of the deformation of sodium chloride, Stepanov[3] showed that on the slip planes, even during static deformation, the temperature can approximate the melting temperature. For a metal this effect must be much weaker because of a considerably greater thermal conductivity.

However, while studying the mechanics of plastic deformation of aluminum crystals with x-rays and an electron microscope, Kolontsova[4] came to the conclusion that plastic deformation is accompanied by a recrystallization of the regions of the crystal adjoining the slip planes. In her experiments she used deformations of the same order as we did.

Thus, the comparatively even distribution of residual stresses can be accounted for by the fact that the process of plastic deformation is accompanied by a local temperature increase in the zones of the traces of slipping which reduces residual distortions of the third kind.

The effect of recrystallization and recovery in our experiments is quite improbable since the tempering temperatures (except for 260°) were low and the tempering time was short.

In both alloys the particles precipitated during tempering in the deformed samples were usually of the same size as the particles in the nondeformed samples, or slightly smaller. The size of the particles in the zones of slipping was the same as of those remote from these zones.

These two facts oblige us to assume that the plastic deformation used in our experiments accelerates decomposition, mainly by increasing the number of decomposition centers, and seemingly has no significant effect on the diffusion coefficient.

It is not asserted that the conclusions reached in this paper apply to other aging alloys, but it is possible that they may prove correct for a number of alloys with melting temperatures relatively close to the deformation temperature, as is the case for the aluminum alloys we have studied.

In conclusion, the writers wish to express their sincere gratitude to A. P. Komar, active member of the Ukrainian Republic Academy of Science, for his comments on their results.

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[1]Kurnosov, Tronina, and Yakutovich, Zhur. tekh. fiz., 18, 197 (1948).
[2]N. N. Davidenkov and Yu. S. Terminasov, Zhur. tekh. fiz., 14, 409 (1944).
[3]A. V. Stepanov, Physik. Z. Sowjetunion, 4, 609 (1933).

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