Anomalous change of Young's modulus in superplasticity

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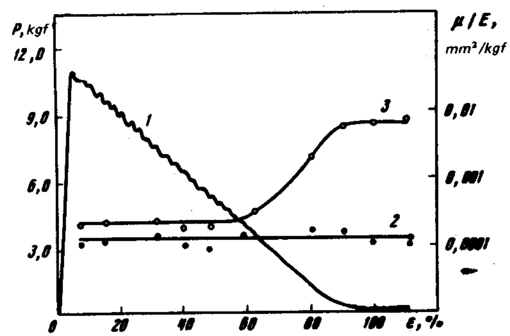
An anomalous change in Young's modulus was observed in the transition of metastable eutectics into the superplastic state.

To develop a theory of plastic deformation of a solid it is important to accumulate experimental facts on one of the extremal states of matter—superplasticity (SP)—which is possessed under certain conditions by all metals and alloys. Investigations of superplastic deformation of various alloys have shown that SP develops in at least two stages.[1,2] In [1] it is predicted that in the second stage, called "true" superplasticity, a quasi-liquid state is produced in the deformed material.

We report here results of x-ray diffraction measurements of SP deformation of the Pb-Sn eutectic, which have made it possible to observe experimentally the onset of the quasiliquid state. The measurements were made with an attachment[3] to the GUR-4 goniometer of an x-ray diffractometer. The construction of the attachment was such that samples could be dilated and the deformation forces could be simultaneously registered. The photography was in iron radiation using as a standard copper powder deposited on part of the surface in the stretched part of the sample. The measurements were made in the angle interval $2\theta = 120.5-126.5°$. The attachment was so mounted on the goniometer that the geometry of the photography remained unchanged. The elastic transverse deformation of the sample in the case of SP deformation was calculated from the change of the inteplanar distance d. At the same time, a strain gauge was used to register the stress corresponding to the change of d. The figure shows a plot of $\mu/E = f(\epsilon)$ for two phases of the Pb-Sn eutectic; here μ is the Poisson coefficient, E is Young's modulus, and ϵ is the strain. The fact that the strains were determined by x-ray diffrac-



Variation of the value of μ/E for the eutectic phases and of the tensile stress during the process of superplastic deformation.

tion and the stresses were determined with a strain gauge has made it possible to use the formula[4]

$$\epsilon = -\frac{\mu}{E}G$$

to calculate the change of the quantity μ/E. It follows from the figure (curve 2) that the value μ/E calculated for the Pb phase of the eutectic remains constant for all stages of the deformation and corresponds to the usual behavior of the elastic constants of a solid.[4]

We note that the crystal lattice of the Pb phase of the investigated eutectic undergoes appreciable microdistortions of the second kind.[3] The present results show that this phase is in a more highly stressed state than the Sn phase during all stages of the deformation.

For the second phase (Sn) we observed a strong increase in the 90% elongation region (curve 3), where the flow stresses become much lower. This instant corresponds on curve 1 to the stage of true superplasticity.[1] The observed change in μ/E is due to the corresponding change of E, since μ remains unchanged in the elastic-deformation region.[4] The abrupt decrease of the modulus E for the Sn phase only upon deformation of the Pb-Sn eutectic shows that the two phases of the alloy behave differently under SP deformation. It can be suggested that the tin plays the role of the quasiliquid matrix[1)] in which the finely-dispersed particles of the second phase are located. The material then behaves like a "Newtonian" liquid.

Thus, the transition to the second stage of superplasticity is connected with a change in the deformation mechanism. The present results indicate that this mechanism is qualitatively due to the appearance of a quasiliquid state of one of the phases of the deformed eutectic.

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1)According to [5], an abrupt change of E is the main attribute of a transition of a material into another aggregate state.

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