

- [3] S.I. Khankina and V.M. Yakovenko, Fiz. Tverd. Tela 9, 578 (1967) [Sov. Phys.-Solid State 9, 443 (1967)].

INFLUENCE OF THE SUPERCONDUCTING STATE ON THE CREEP OF METALS

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In mechanical tests of metals near absolute zero, when thermally activated processes are suppressed to a considerable degree, the conduction electrons may play an important role in interactions with moving dislocations. The clarification of the influence of normal electrons on the mechanical properties has been recently the subject of a number of experimental [1 - 5] and theoretical [6 - 7] investigations.

Since it is difficult to separate experimentally in pure form the electronic component dislocation deceleration, the most suitable objects for this purpose are superconducting metals in which it is possible to vary extensively the density of the normal electrons. It was shown [1, 3 - 5] that niobium or lead loses strength on going over from the normal to the superconducting state, owing to the increase of the energy scattered by the moving dislocations.

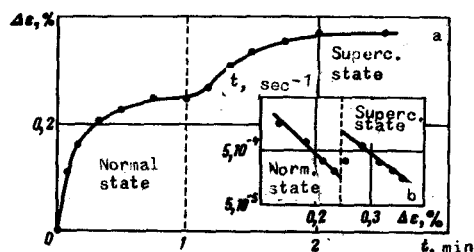


Fig. 1. Change of thallium deformation $\Delta\epsilon$ vs. time (a) and of deformation rate vs. degree of deformation (b) in the transition creep state during the change from the normal to the superconducting state ($T = 1.8^\circ\text{K}$, $\sigma = 3.2 \text{ kg/mm}^2$).

The present paper is devoted to a verification of the presence of this phenomenon in a number of superconductors under creep conditions at temperatures $1.80 - 4.2^\circ\text{K}$.

The investigations were performed on metals with different types of crystal lattice: In (99.9999%), Tl ($> 99.999\%$), Hg ($> 99.999\%$), and Sn (99.9995%). The Hg samples were plane-parallel plates thickened on the ends, with working-section dimensions $20 \times 4 \times 3 \text{ mm}$. They were obtained by slow-cooling crystallization in a dismantlable steel mold. The samples of the other metals had the form of plates measuring $40 \times 4 \times 1.5 \text{ mm}$. The In and Tl were annealed at room temperature for a day; the Sn samples were annealed at 100°C in vacuum $1 \times 10^{-5} \text{ mm Hg}$ for one hour. The average grain dimension in all metals was $1.5 - 3 \text{ mm}$.

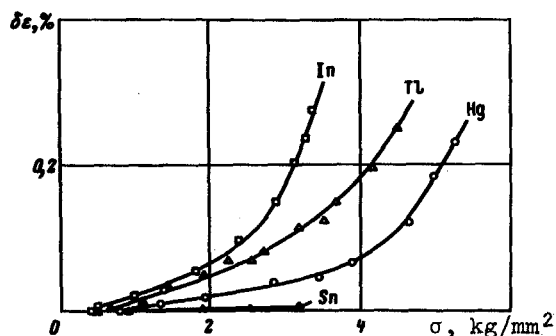


Fig. 2. Loss of strength $\delta\epsilon$ vs. stress for In ($T = 2.3^\circ\text{K}$), Te ($T = 1.8^\circ\text{K}$), Hg ($T = 3.5^\circ\text{K}$), and Hg ($T = 1.8^\circ\text{K}$).

The creep tests were performed under stepwise loading conditions with gradual increase of the load up to failure, using apparatus [8] with a modified

cryostat construction having a superconducting solenoid intended to change the metal (at $T < T_c$) from the superconducting state to the normal state. A longitudinal magnetic field up to 3500 Oe was used.

The experiments have shown that in all the investigated metals (In, Tl, Hg, Sn, and Pb [5]) in the superconducting state, loss of strength is observed during the creep-test process, consisting of an appreciable increase of the creep rate, which increases with decreasing temperature below T_c .

Figure 1a shows by way of an example a section of the creep curve of Tl at 1.8°K and at a stress $\sigma = 3.2 \text{ kg/mm}^2$, corresponding to the transition stage in the normal and superconducting states, while Fig. 1b shows a plot of the deformation rate against the deformation in the presence of such a transition. It is seen that when the superconducting states set in (with the field turned off), a loss of strength takes place (the deformation increases on going from the normal state to the superconducting state), together with a sharp increase of the creep rate, followed by its slow attenuation. Attention is called to the fact that the change of the creep rate lags the transition from the normal state to the superconducting state (and vice versa) in time (incubation period). Similar curves were observed for Tl at different applied stresses. Analogous relations were plotted for all the investigated superconductors. As already noted in [5], the loss of strength depends on the point on the creep-attenuation curve where the transition is completed, and also on the applied load.

The loss of strength increases with increasing effective stress in all the investigated metals (Fig. 2). In spite of the fact that In, Tl, Hg, and the previously investigated Pb [5] have different crystal lattices, all experience a considerable loss of strength in the superconducting state, apparently because of the high plasticity and the high dislocation mobility in these metals. The loss of strength of Sn is small, probably because of its brittleness in this temperature region.

When the temperature drops below T_c , the loss of strength increases sharply (Fig. 3). It seems that a possible mechanism of the discovered phenomenon is

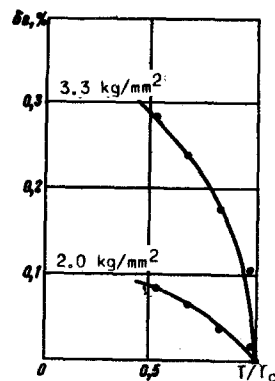


Fig. 3. Change of the loss of strength of indium vs. temperature, for two values of the stress.

the decrease of the deceleration of the moving dislocations as the normal conduction electrons are exhausted. Some of the electrons do not take part in the processes of this type, owing to the presence of the energy gap.

- [1] I.Ya. Gindin and Ya.D. Starodubov, *Fiz. Metal. Metallov.* 15, 736 (1963).
- [2] W.P. Mason, *Appl. Phys. Lett.* 6, 111 (1965).
- [3] J. Kojuma and T. Suzuki, *Phys. Rev. Lett.* 21, 896 (1968).
- [4] V.V. Pustovalov, V.I. Startsev, and V.S. Fomenko, *Fiz. Tverd. Tela* 11, 1382 (1969) [*Sov. Phys.-Solid State* 11, 1119 (1969)].

- [5] I.A. Gindin, B.G. Lazarev, Ya.D. Starodubov, and V.P. Lebedev, Dokl. Akad. Nauk SSSR 188, 803 (1969) [Sov. Phys.-Dokl. 14 (1970)].
- [6] V.Ya. Kravchenko, Fiz. Tverd. Tela 8, 927 (1966) [Sov. Phys.-Solid State 8, 740 (1966)].
- [7] C.P. Huffman and N. Louat, Phys. Rev. 176, 773 (1968).
- [8] I.A. Gindin, S.F. Kravchenko, Ya.D. Starodubov, and V.M. Godzhaev, PTE No. 3, 169 (1963).

HYDROSTATIC EFFECT IN A BINARY SOLUTION NEAR THE CRITICAL DISSOLUTION POINT

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The question of the existence of the theoretically-predicted [1, 2] hydrostatic effect near the critical lamination point of a solution has been under discussion in recent years. According to [1, 2], the concentration gradient over the height of a column of liquid is $dx/dH \sim (\partial\mu/\partial x)_{P,T}^{-1}$. If $(\partial^3\mu/\partial x^3)_{P,T} \neq 0$ at the critical point, then it follows that at the critical point the height variation of the concentration is given by $x - x_k = \Delta x \sim (H - H_0)^{1/3}$, where H_0 is the position of the lamination solution line [2].

Using the Toepler method, we investigated the distribution of the concentration in a binary CH_4 - CF_4 solution having an upper critical mixing point ($T_c = 94.72^\circ K$; $x_c = 43.5\% CF_4$). The connection between the experimentally-determined gradient of the refractive index and the concentration gradient was obtained by using the Lorenz-Lorentz equation. The refractive indices of the components were taken from [4]. The critical-concentration solution was investigated in a previously-described cryostat [5], with a thermostat accuracy $\pm 0.001^\circ K$.

The solution was stirred at temperatures above T_c until it became completely homogeneous. The degree of homogeneity was monitored against the shadow picture; the solution was then kept at a thermostatically controlled temperature until the variation of the concentration gradient stopped completely. As a result, inhomogeneities of the composition along the height of the liquid column were observed. The time required to reach equilibrium depended on the degree of approach to T_c , and reached 50 - 70 hours at $T - T_c = \Delta T \sim 1^\circ K$; it increased sharply with decreasing ΔT . At $\Delta T \sim 0.2^\circ K$, no equilibrium was reached even after about 300 hours.

The measurements were performed either in the presence of a "vapor-liquid" interface inside the chamber or with the chamber completely filled with liquid, with a meniscus in the supply capillary entering the lateral part of the chamber. In the former case, a concentration gradient was produced near the surface of the liquid immediately after stirring. The surface layers became richer in methane, the enrichment increasing the closer the temperature to critical. The thickness of these layers reached 1 - 10 mm and also increased on approaching T_c . In addition, drops of liquids enriched with the heavy component were precipitated from the surface layer (they could be seen only on the shadow picture). The rate of drop formation increased on approaching the lamination point, and led to the occurrence of a concentration gradient even in the lower part of the chamber. As time went on, the process of drop formation stopped and the concentration in the lower part of the chamber became equalized, while a concentration gradient still remained in the surface layer. The described effects were observed in a temperature interval up to $\Delta T \sim 16^\circ K$ above critical.