Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (23–24 April 1986)

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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on April 23 and 24, 1986 at the S. I. Vavilov Institute of Physics Problems of the USSR Academy of Sciences. The following reports were presented at the session:

April 23

1. *I. V. Aleksandrov, A. F. Goncharov, A. N. Zisman, I. N. Makarenko, and S. M. Stishov.* Investigations of alkalihalide crystals and noble gases at superhigh pressures (control of the state, phase transitions, metallization).

2. *I. T. Belash, V. F. Degtyareva, and E. G. Ponyatovskiĭ.* New phases of the Hume-Rothery type—superconductors obtained under high pressures.

3. *V. V. Brazhkin, V. I. Larchev, S. V. Popova, and G. G. Skrotskaya.* Metallic glasses and amorphous semiconductors, obtained by quenching from the melt under high pressure.

4. *V. E. Antonov, I. T. Belash, and E. G. Ponyatovskiĭ.* Hydrides: investigations under high hydrogen pressures.

April 24

5. *V. N. Gavrin, E. A. Gavryuseva, and G. T. Zatsepin.* Present status of and prospects for solar neutrino astronomy.

6. *A. A. Ruzmaĭkin.* Magnetic fields on the sun.

7. *M. B. Voloshin, M. I. Vysotskiĭ, and L. B. Okun'.* Possible electromagnetic properties of the neutrino and variations of the solar neutrino flux.

Summaries of five of the reports are published below.

I. T. Belash, V. F. Degtyareva, and E. G. Ponyatovskiĭ. *New phases of the Hume-Rothery type—superconductors obtained under high pressures.* The possibility of producing high pressures has given rise to intensive study of the dependence of the state of matter and its structure and properties on a new thermodynamic parameter—the pressure. In characterizing the extensive path to the development of these investigations, three stages should be noted: I) the study of the polymorphism of elements under high pressures and construction of *T-P* diagrams; II) study of polymorphism of compounds, and, III) construction of volume *T-C-P* diagrams of binary and multicomponent systems. Up to now the first stage has been practically completed in the accessible pressure range. The second stage is methodologically linked with the third stage, since the *T-P* diagram for a binary compound consists of the isoconcentration section of the volume *T-C-P* diagram.

The problem addressed at the third stage at first glance appears to be immense. One would think that the introduction of a third parameter (pressure) should make the existing complicated picture of the collection of diverse *T-C* phase diagrams at normal pressure much more complicated as a result of the polymorphism of the pure components, polymorphic transformations of intermediate phases and compounds, and also the appearance of numerous new intermediate phases. In reality, however, the synthesis of new phases under pressure and the study of their structure and properties gives important new information, which enables uncovering a number of general rules governing phase formation in multicomponent systems and thereby simplifying the general picture of phase equilibria in multicomponent systems.

Systematic experimental investigations of *T-C-P* diagrams have been conducted at the Institute of Solid State Physics of the USSR Academy of Sciences for the last two decades. Binary systems of B elements were chosen for the model systems. These systems are convenient for a number of reasons: the existence of polymorphism of the component elements under pressure, the simple form of the *T-C* diagrams, low working parameters (pressure, temperature), and abundance of intermediate phases obtained under pressure and their similarity to the phases quenched from the liquid state. The phase transformations were recorded by the methods of DTA and resistometry under pressure, while the structure and the superconducting properties were studied on "quenched" alloys under normal pressure.

It turned out that the evolution of phase equilibria in binary systems is determined by the "homology rule": the pressure produces the same changes in the phase equilibria as does the replacement of one of the components by a heavier element of the same group. The *T-C-P* diagrams of the homologous systems contain similar isobaric *T-C* sections (at higher pressure in the case of systems with a lighter component). Examples of homologous systems are: Zn–Sb and Cd–Sb,[1] Pb–Sb and Pb–Bi, In–Sb and In–Bi.[2]

The general sequence of structural types for intermediate B-B phases has been established.[2] As the electron density (n_e) of the alloy increases, a transition is observed to struc-

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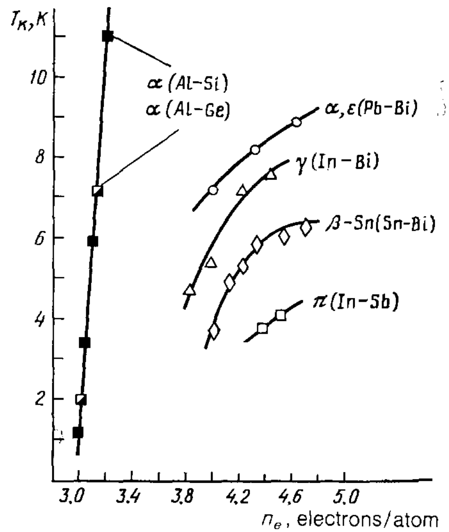

FIG. 1. Superconducting transition temperature of some B-B phases obtained under pressure.[2,3]

tures with a lower packing density (coordination number):

$$\text{fcc, hcp } (12) \rightarrow \text{bcc } (8) \rightarrow \text{simple hexagonal } (2+6) \rightarrow \beta\text{-Sn}(4+2) \rightarrow \text{simple cubic } (6).$$

For metallic phases with $n_e > 3$ electrons/atom the characteristic structures are simple hexagonal (γ) and simple cubic (π), and also their distorted variants. These phases are a continuation of a series of well-known electronic Hume-Rothery phases, characteristic for alloys of B elements with $n_e = 1$–2 electrons/atom.

The range of B-B phases, substantially extended over the last decade, makes it possible to study correlations between the superconducting properties (T_c), structure, and electron density of alloys (see Fig. 1).

1. Within the limits of stability of each structural type T_c increase monotonically as n_e increases. It is interesting to note that in following each curve, in accordance with the data from x-ray structural analysis, the electron density n_e/v electrons/Å^3 remains approximately constant.

2. For the same values of n_e in different alloys of elements of V and VI periods, close values of T_c were obtained for phases with the same structure.

3. Comparison of data on T_c for alloys with the same electron density but different structure shows that higher values of T_c are characteristic for the more compact structures.

4. For phases with the same type of structure, higher values of T_c are achieved in alloys with lighter components. For fcc solid solutions of silicon in alumina a value of $T_c = 11$ K, the highest value for alloys of transition elements, was obtained.[3]

The new class of superconducting B metals studied, in view of the simplicity of their electronic structure, high symmetry of their crystalline structure, and also the simple and unique correlations between T_c, the electron density, and the structure, is a convenient model system for further development of the theory of superconductivity. We note that this class of superconductors was ignored in previously published reviews on superconductivity, including the last two reviews in Uspekhi Fizicheskikh Nauk.[4]

In conclusion, we would like to call attention to an interesting effect of the pressure on the structural state of alloys, though not predicted beforehand, but still entirely natural and explainable—the process whereby alloys are rendered amorphous. The amorphous state appears in alloys with "quenched" high-pressure phases as an intermediate metastable step along the path back to the equilibrium state. As a rule, we observe the amorphous state in alloys which have in the equilibrium state a semiconducting phase (in the alloys Zn–Sb, Cd–Sb, and Al–Ge, these are ZnSb, CdSb, and Ge, respectively).

[1] I. L. Aptekar, I. T. Belash, and E. G. Ponyatovskiĭ, High Temp.-High Press. **9**, 641 (1977); I. T. Belash and E. G. Ponyatovskiĭ, *ibid.*, 645.
[2] V. F. Degtyareva and E. G. Ponyatovskiĭ, Fiz. Tverd. Tela **24**, 2672 (1982) [Sov. Phys. Solid State **24**, 1514 (1982)].
[3] V. F. Degtyareva, G. V. Chipenko, I. T. Belash, O. I. Barkalov, and E. G. Ponyatovskiĭ, Phys. Status Solidi A **89**, K127 (1985).
[4] M. R. Beasley and T. H. Geballe, Phys. Today **37**, 60 (1984) [Russ. Transl., Usp. Fiz. Nauk **148**, 347 (1986)]; A. I. Golovashkin, Usp. Fiz. Nauk **148**, 363 (1986) [Sov. Fiz. Usp. **29**, 199 (1986)].