A. I. Golovashkin and A. N. Lykov. *Submicron superconducting structures.* At the present time, superconducting structures of submicron size and systems consisting of such structures are of considerable interest for superconductor electronics. The transition to a submicron level allows one, first of all, to increase the packing density of elements, to decrease the signal transmission time, to decrease the capacitance and the power loss at high-frequency applications, etc. Secondly, the smallness of a coherence length in the most interesting superconductors (transition metals, their alloys and high-temperature compounds) also limits the size of weak superconducting contacts, at which the "classical" Josephson effect can be observed. In the "vortex bridges" the achievement of a "single-line" coherent motion of vortices also requires the decrease in size. There are also some other reasons for the increased interest in submicron superconducting structures. New physical phenomena in these structures[1], and other important results show the relevance and usefulness of work in this direction.

The principal and most promising method of obtaining submicron superconducting structures for wide use in microelectronics is lithography. With the help of electron lithography it was possible to obtain Nb bridges with a width of 250Å and a length of 0.8 μ.[2] Using special "tricks", it is also possible to obtain small quantities of such structures using photolithigraphy.[3]

Let us mention the most interesting simple submicron superconducting structures. The tunnel contact Nb–I–Nb of submicron dimensions is obtained with the help of a "suspension bridge" (formed by the photolithographic method). The end-face tunnel junctions and the junctions of the *S-N-S* type, in which one of the dimensions (the length) is determined by the thickness of a metal film. This method was used to make junctions with two Nb electrodes. (see Ref. 4). The contacts Nb_3Ge–Cu–Nb_3Ge with an end-face (vertical) bridge of Cu made in Ref. 5 have demonstrated the ideal Josephson behavior over a very wide range of temperatures (1.4–19 K). Based on these bridges, interferometers with high energy sensitivity were developed.

Until now there still exists an interest in a number of experimental methods of obtaining submicron superconducting structures. Among them are: double-scribing, various methods of creating shunts between two films of superconductors, separated by a layer of a dielectric, pressure and point contacts, etc. In addition to the Josephson effect, these contacts have also exhibited on their *I-V* curves a number of interesting phenomena such as excess current, subharmonics and harmonics of the superconducting energy gap. An original element is the "cut", i.e., a thin superconducting film cut across its entire width. When the cut has a small width this contact has the properties of a tunnel contact.[6]

The properties of the Dayem bridges made from high-temperature superconductors of the type A15 and B1 are determined by the motion and pinning of the flux quanta. A number of interesting physical effects in such bridges has been found—coherent motion of vortices synchronized by a microwave field, amplitude oscillation of the current steps in a magnetic field, appearing in a microwave field, oscillation of voltages on the bridge, caused by penetration of vortices, stimulation of critical current and its oscillations with microwave power, subharmonics of current steps, subharmonics of the energy gap singularity on *I-V* curves.[7,8] It became possible to determine experimentally the most important parameters of the pinning phenomenon for individual vortices (the potential well depth of the pinning centers, etc.).

Systems of superconducting submicron elements are also intensively studied. Linear arrays of tunnel junctions and submicron bridges consisting of dozens of elements have been developed. It has been demonstrated that with the help of a magnetic field one can phase such systems. Using these sysems as generators, one can observe an increase in power by a factor N^2 and a narrowing of the generated line by a factor of N, where N is the number of elements. In Ref. 9 it was possible to observe the phase coherence of a two-dimensional system consisting of 20,000 tunnel junctions of submicron size.

Over the last several years there have been studies of various two-dimensional superconducting structures for the purpose of using the coherent motion of the Abrikosov lattice of vortices for generation of electromagnetic radiation. Among those structures are corrugated films (with periodically modulated thickness), lattices of pinning centers, granulated and layered structures. For the formation of a lattice of vortices one needs to have the magnetic fields close in magnitude to the upper critical magnetic field. The necessity to achieve that the size of the lattice of vortices would be commensurate with the defect lattice leads to submicron periods of the latter. The synchronous motion of dozens of vortex chains has been observed experimentally.

The research area of submicron superconducting structures is an interesting and rapidly developing direction.

[1]K. K. Likharev, Usp. Fiz. Nauk **139**, 169 (1983) [Sov. Phys. Usp. **26**, 87 (1983)].
[2]A. N. Broers and R. B. Libovitz, FISE: AIP Conference Proceedings, **44**, 289 (1978).

[3]M. D. Fener and D. E. Prober, Appl. Phys. Lett. **36**, 226 (1980).
[4]A. L. Gudkov, Yu. E. Zhuravlev, V. I. Makhov, and A. V. Tyablikov, Pis'ma Zh. Tekh. Fiz. **9**, 1061 (1983) [Sov. Tech. Phys. Lett. **9**, 457 (1983)].
[5]A. DeLozanne, M. Dilorio, and M. R. Beasley, Appl. Phys. Lett. **42**, 541 (1983).
[6]A. I. Golovashkin, A. N. Lykov, L. I. Makhashvili, and E. V. Pechen', Fiz. Tverd. Tela (Leningrad) **20**, 2159 (1978) [Sov. Phys. Solid State **20**, 1247 (1978)].
[7]A. I. Golovashkin, A. N. Lykov, and S. L. Prishchepa, Zh. Eksp. Teor. Fiz. **76**, 1316 (1979) [Sov. Phys. JETP **49**, 668 (1979)].
[8]A. N. Lykov and S. L. Prishchepa, Fiz. Tverd. Tela. (Leningrad) **26**, 2985 (1984) [Sov. Phys. Solid State **26**, 1801 (1984)].
[9]R. F. Voss and R. Webb, Phys. Rev. **B25**, 3446 (1982).

Translated by Andrew Petelin