found. The values of the spin-orbital and Coulomb splittings of three near-degenerate bands and the concentration dependence of the gaps and the chemical-potential level have been determined in alloys of cadmium with isovalent impurities (~10 at.%).[2,4] The characteristics of the scattering caused by the disorder of the potential have been found for the above systems. Rather far-reaching extrapolation of the spectral concepts that have been adopted for ideally ordered systems is found to be admissible when it is used to describe the electron structure of the alloys.

A critical point in degenerate bands of beryllium has been detected through the anomalous maximum in the diamagnetism even at ~800 °K, making it possible to determine the temperature dependence of the chemical-potential level up to $T \sim 1300$ °K.[5] As for the behavior of the chemical-potential level, the susceptibility properties indicate that its position in the middle of the energy gaps on the corresponding Bragg planes is the basic factor that stabilizes long-period superstructures in self-ordering alloys.

Detailed examination of these and other examples points to the conclusion that the parameters of the single-electron spectra of simple metals (especially the energy gaps, which are an immediate consequence of crystalline potential) can be determined with the aid of the orbital susceptibility with better accuracy than is obtained from existing *a priori* and empirical calculations of the spectrum, even when the Fermi surface is strongly diffused by temperature or scattering. We do not now have any other method capable of competing with the constant component of susceptibility in subtlety of electron-spectrum analysis over a broad range of concentrations and temperatures, and the latter can be recommended as an effective tool for investigation of disordered metallic systems.

[1]B. I. Verkin, L. B. Kuz'micheva, and I. V. Svechkarev, Pis'ma Zh. Eksp. Teor. Fiz. **6**, 757 (1967) [JETP Lett. **6**, 225 (1967)].

[2]B. I. Verkin, L. B. Kuzmicheva, A. A. Maryakhin, and I. V. Svechkarev, in: Proc. LT-11, St. Andrews, 1968, V. 2, p. 1121.

[3]H. Fukuyama, Progr. Theor. Phys. **45**, 704 (1971).

[4]I. V. Svechkarev, Izv. Akad. Nauk SSSR, Ser. Fiz. **42**, 1701 (1978).

[5]G. E. Grechnev, I. V. Svechkarev, and Yu. P. Sereda, Zh. Eksp. Teor. Fiz. **75**, 993 (1978) [Sov. Phys. JETP **47**, 502 (1978)].

I. K. Yanson and I. O. Kulik. *Microcontact phonon spectroscopy in metals.* Since the appearance of Sharvin's paper,[1] weak electrical contacts between metals have interested investigators as a tool for study of energy spectra. References [2] were concerned with the effects of focusing of electrons injected from microcontacts 1–10 μm in diameter, which can be used to reconstruct Fermi-surface parameters. The present paper reports on a series of experimental and theoretical studies of microcontacts with smaller diameters ($d \sim 100$ Å), which enable us to obtain direct information on the phonon spectra and the intensity of the electron-phonon interaction.[3-5] This procedure has been used to investigate Pb, Zn, Cd, Sn, In, Al, Cu, Ag, Au, Na, Li, Ni, Co, and Fe—normal metals, superconductors, and ferromagnets. The microcontacts were produced by either of two methods—by weak breakdown of film tunnel transitions with rather high resistance or by pressing a sharp needle against a metallic "anvil." In the latter case, the metals forming the contact may be single crystals. At the point of application, local destruction of the oxide film is accompanied by the formation of a direct metal-to-metal contact. Its diameter can be determined from its resistance by the formula

$$\frac{1}{R}=\frac{e^2 SS_F}{2(2\pi\hbar)^3}, \qquad (1)$$

which is valid at the Knudsen limit (the diameter of the contact is smaller than the electron free path); here S is the contact area and S_F is the area of the Fermi surface.

The current density in the contact cross section reaches very large values ($j \sim 10$ A/cm²), which correspond to drift velocities on the order of the speed of sound $S \sim 10^5$ cm/sec. Under these conditions, the electron flux generates phonons whose frequency is determined by the voltage applied to the contact. At the same time, the contact is not heated by the flowing current because the Joule heat is released over the inelastic relaxation length ($l_e \geq 10^3$ Å), which is large compared to the contact diameter. The volt-ampere characteristic of the contact becomes nonohmic, reflecting the dynamics of electron scattering on the phonons.

Figure 1 shows a typical "microcontact spectrum"—a curve of the second derivative of the current with respect to the voltage plotted against V (solid curve) in the case of Cd. The spectra have a distinct structure that reproduces well on different samples. The positions of the maxima on the curve of $V_2(eV) \sim d^2V/dI^2(V)$

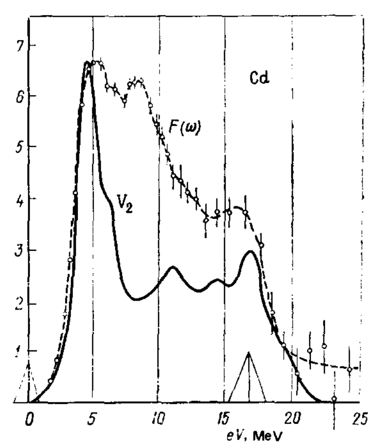

FIG. 1.

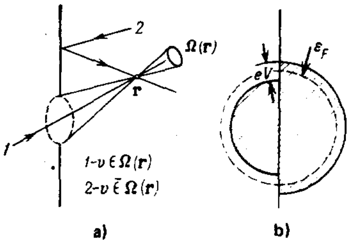

FIG. 2.

correspond closely to the maxima of the phonon density of states $F(eV)$ reconstructed from neutron data [the dashed curve is the $F(eV)$ relation for Cd[6]]. According to theory, the value of the second derivative of the current with respect to the voltage in the microcontact is given by

$$\frac{d^2 I}{dV^2} = -4e^3 \Omega_{\text{eff}} N(0) G(eV), \tag{2}$$

where $N(0)$ is the density of electron states on the Fermi surface, Ω_{eff} is the effective phonon-generating volume ($\Omega_{\text{eff}} \sim d^3$), and $G(\omega)$ is the "transport" function of the electron-phonon interaction, $G(\omega) = L^2(\omega)F(\omega)$:

$$G(\omega) = \frac{N(0)}{2\hbar} \frac{\int \frac{dS_p}{v_\perp} \int \frac{dS_{p'}}{v'_\perp} W_{\mathbf{p}-\mathbf{p}'} \, \delta(\omega - \omega_{\mathbf{p}-\mathbf{p}'}) K(\mathbf{p}, \mathbf{p}')}{\int \frac{dS_p}{v_\perp} \int \frac{dS_{p'}}{v'_\perp} \cdot 1}. \tag{3}$$

Here $\omega_\mathbf{q}$ is the phonon dispersion law and $W_{\mathbf{p}-\mathbf{p}'}$ is the squared matrix element of the electron-phonon interaction, averaged over the Fermi surface with the geometric form factor $K(\mathbf{p}-\mathbf{p}')$. The latter enables us to investigate the anisotropy of the G-functions, which is conspicuous to experiments performed to study single crystals in various orientations. The electron distribution on the aperture has the form shown in Fig. 2b. Only scattering events from states $p_z > 0$ to states $p'_z < 0$ contribute to the current.

The experimental studies indicate that $\tilde{\alpha}^2(\omega)$ is practically constant for multivalent metals, i.e., the matrix element of the electron-phonon interaction depends weakly on energy. For the alkali metals Na and K, the form factor $\tilde{\alpha}^2(\omega)$ increases with ω. The microcontact spectra of these metals contain a strong background (nonzero value of the second derivative at $\omega > \omega_{\max}$), evidently because of poor structure, i.e., the short elastic-scattering length. For noble metals, in which the specifics of the d-electrons are manifested, the function $\tilde{\alpha}^2(\omega)$ decreases with increasing energy, so that the line intensities of longitudinal acoustic phonons are much lower than those of the transverse phonons. This last property is seen most distinctly in the "true" d-metals Fe, Co, and Ni.

Together with the phonon singularities in the energy range of the order of the Debye temperature Θ_D (i.e., $eV > 0.05$ eV), the microcontact spectra of ferromagnetic metals[7] show a strong anomaly at energies corresponding to the magnon energy. Theoretical interpretation indicates that a transition from the Knudsen to the Maxwell regime of current flow takes place at these high energies ($l < d$ instead of $l > d$), with the result that the contact heats up. The position of the singularity is determined by the relation $eV_C = 3.6kT_C$ (T_C is the Curie temperature), which is well confirmed in experiment. Measurements of microcontact spectra in this energy range can be used to reconstruct the temperature dependence of the part of the resistance due to scattering on magnons, $\rho_{\text{mag}}(T)$, at high current densities that are inaccessible in ordinary experiments.

[1]Yu. V. Sharvin, Zh. Eksp. Teor. Fiz. **48**, 984 (1965) [Sov. Phys. JETP **21**, 655 (1965)].

[2]V. S. Tsoĭ, Pis'ma Zh. Eksp. Teor. Fiz. **19**, 114 (1974) [JETP Lett. **19**, 70 (1974)]; Zh. Eksp. Teor. Fiz. **73**, 289 (1977) [Sov. Phys. JETP **46**, 150 (1977)].

[3]I. K. Yanson, Zh. Eksp. Teor. Fiz. **66**, 1035 (1974) [Sov. Phys. JETP **39**, 506 (1974)]; Fiz. Tverd. Tela (Leningrad) **16**, 3595 (1974) [Sov. Phys. Solid State **16**, 2337 (1975)]; Fiz. Nizk. Temp. **3**, 1516 (1977) [Sov. J. Low Temp. Phys. **3**, 726 (1977)].

[4]I. O. Kulik, A. N. Omel'yanchuk, and R. I. Shekhter, Sol. State Comm. **23**, 301 (1977); Fiz. Nizk. Temp. **3**, 1573 (1977) [Sov. J. Low Temp. Phys. **3** (1977)].

[5]I. K. Yanson and I. O. Kulik, in: Proc. LT-15, Grenoble, France, **3** (1978).

[6]I. P. Eremeev, I. P. Sadikov, and A. A. Chernyshev, Fiz. Tverd. Tela (Leningrad) **18**, 1652 (1976) [Sov. Phys. Solid State **18**, 960 (1976)].

[7]B. I. Verkin, I. K. Yanson, I. O. Kulik, O. I. Shklyarevskiĭ, A. A. Lysykh, and Yu. G. Naĭdyuk, Sol. State Comm., 1978.

V. P. Galaĭko and V. M. Dmitriev. *Nonequilibrium superconductivity in specimens with small transverse dimensions.* Nonequilibrium superconductivity is interesting for the fact that new and unusual properties may be expected under nonequilibrium conditions in superconductors by virtue of their special sensitivity to external disturbances. These conditions can be set up most easily throughout the entire volume of the superconductor by using specimens with small transverse dimensions and, for example, passing a current higher than the critical value through the specimen or exposing it to electromagnetic radiation. It is possible as a result to observe certain new physical aspects of superconductivity, which are the subject of the present note. They concern the nature of resistive (i.e., dissipative but not normal) current states in narrow superconductive channels and stimulation of superconductivity in these channels by external electromagnetic radiation. From the standpoint of superconductor kinetics, both of these phenomena are determined by the properties of the essentially nonequilibrium electron distribution over microstates in the presence of the superconducting condensate.

1. *Resistive current states.* When a supercritical current is passed through a narrow semiconducting