The possibility of increasing diamagnetic susceptibility of pyrocarbon

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A large increase of diamagnetism of pyrocarbon due to a decrease in concentration of the carriers and dependence of the magnetic susceptibility on the intensity of the magnetic field have been observed. The observed maximum diamagnetic susceptibility ($\sim 0.2\%$ of $-1/4\pi$) exceeds the values of all materials in the literature except superconductors.

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The search for materials having a large diamagnetism, which is conserved in a wide range of magnetic fields and temperatures, is of considerable practical interest for construction of different devices using the effect of magnetic levitation. In this respect, of great interest are the quasi two-dimensional pyrocarbon materials with an energy spectrum close to the gapless semiconductor with a conic dispersion law,[1] in which a strong increase of diamagnetism can be expected as the Fermi level approaches the conic point.

In this paper we investigated by the modulation method[2] the differential magnetic susceptibility and the galvanomagnetic properties in the range of magnetic fields up to 80 kOe and temperatures from 2 to 300 K in a number of samples of quasi two-dimensional pyrocarbon precipitated at different temperatures.

Figure 1 shows the results of measuring $\chi_{\parallel}$ (the field is parallel to the hexagonal C axis) as a function of the magnetic field H for four pyrocarbon samples (curves 1–4) at 4.2 K. The susceptibility $|\chi_{\parallel}|$ in weak fields increases slightly, which apparently is attributable to the paramagnetic impurities, remains constant and beginning at a certain field H_k decreases linearly in first approximation with increasing magnetic field.

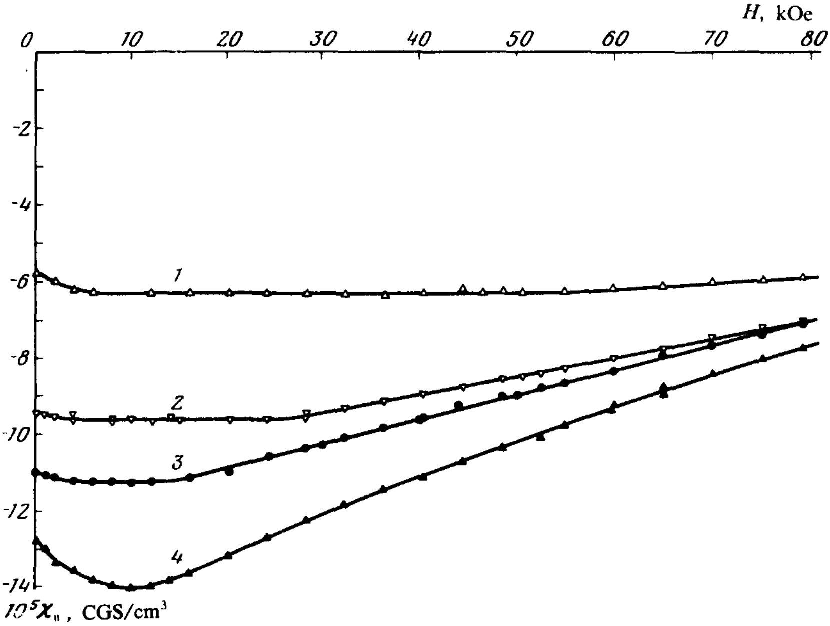

FIG. 1.

According to the galvanomagnetic measurements, all the samples have *p*-type conductivity. The concentration of holes $n_p|_{H\to 0}$ in a weak field at 4.2 K is 5.7, 2.8, 1.5, and 0.6×10^{18} cm^{-3}, respectively, for samples 1–4. The value of H_k decreases with decreasing concentration and the maximum value of $|\chi_{\parallel}|_{max}$ increases. Figure 2 shows the dependences of $|\chi_{\parallel}|_{max}$ (curve 1) and H_k (curve 2) on $n_p|_{H\to 0}$.

For a purely two-dimensional spectrum the concentration of the carriers is directly proportional to the extremal cross section of the Fermi surface. Therefore, the field at which the ultra quantum region starts can be estimated according to the formula: $H_{uq} = \pi\hbar^2 c e^{-1} n_p d$, where d is the interlayer spacing in the crystal lattice ($\approx$3.44 Å). The estimate of H_{uq} for samples 1–4 gives the values 42.9, 21.1, 11.3, and 4.5 kOe, respectively, which are close to the values of H_k. Apparently, H_k correspond to the propagation of the fields to the ultra quantum region. The experimental dependence of H_k on $n_p|_{H\to 0}$ (see Fig. 2) is almost linear, which indicates that the given samples have a quasi two-dimensional spectrum.

The diamagnetism increases with decreasing concentration of the carriers, which indicates that the contribution to $\chi_{\parallel}$ comes predominantly from the filled bands. A decrease of $|\chi_{\parallel}|$ in the ultra quantum region of the fields, in which the contribution from the carriers to the differential susceptibility is small, is apparently attributable to variation of the contribution from the filled bands.

The maximum value $|\chi_{\parallel}|$ of the pyrocarbon samples obtained by us, which is $\sim$0.2% of $-1/4\pi$, exceeds that of the pyrographite single crystal by a factor of $\sim$2 at low temperature and by $\sim$1.5 at room temperature. The observed maximum diamagnetic susceptibility exceeds the values in the literature for all but the superconducting

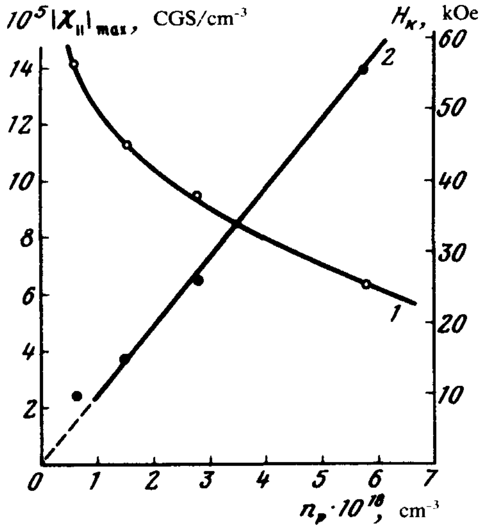

FIG. 2.

materials. As seen in Fig. 2, the diamagnetism of pyrocarbon can be increased by further decreasing the concentration of the carriers.

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