V. M. Pudalov, S. G. Semenchinskiĭ, and V. S. Édel'man. *Charge and potential of an inversion layer in a metal-insulator-semiconductor structure in a quantizing magnetic field.* When a voltage U_g is applied to the gate of a silicon metal-insulator-semiconductor (MIS) structure, a 2D conducting layer of charge carriers forms near the surface of the semiconductor. The carrier density n_s and thus their Fermi level can be controlled by varying U_g. If this structure is placed in a magnetic field, it becomes possible to observe the inverse effect: a change in U_g during quantum oscillations of the Fermi level at a fixed charge in the layer. A study of these oscillations, which were discovered in Refs. 1 and 2, yields information on the energy spectrum of the electrons in the magnetic field.

We have carried out experiments with (001)Si-MIS structures with an electron inversion channel. The structures have dimensions of 5×0.8 mm, a capacitance ~700 pF, and a carrier mobility $\sim 3.5 \cdot 10^4$ cm$^2 \cdot$ V/s at $T \sim 1$ K. The measurements are taken with an electrometer with an input current less than 10^{-14} A with the voltage source disconnected from the gate. Figure 1 shows representative recordings of the oscillations in the voltage between the gate and the contact to the channel.

Each of the Landau levels in the electron inversion layer

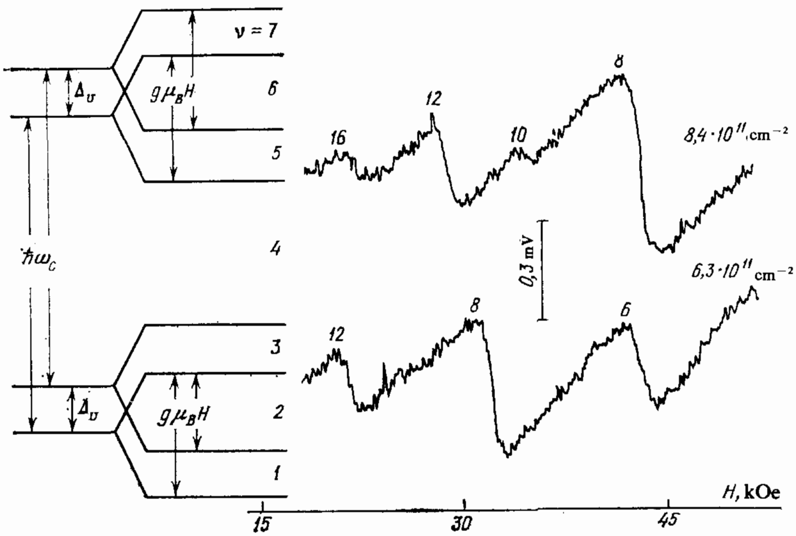

FIG. 1. The potential difference between the gate and the inversion layer as a function of the magnetic field H at two electron densities (given at the right of the curves) at $T = 1$ K. The numbers above the curves are the numbers of completely filled Landau levels. Shown at the left is the level scheme in a magnetic field.

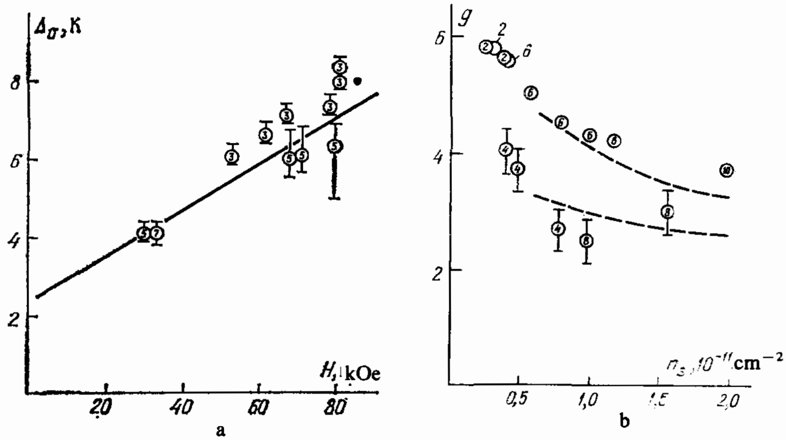

FIG. 2. a—Δ_v as a function of the magnetic field for various numbers of filled Landau levels (● is a datum from Ref. 5); b—dependence on the density n_s of the maximum effective g-factor (at $\nu = 2,6$) and of the minimum effective g-factor ($\nu = 4,8$) (the dashed curves are from Ref. 6).

in a (001)Si-MIS structure in a magnetic field splits into four sublevels because of the lifting of the valley and spin degeneracy.[3] Until recently, no reliable experimental data were available on the valley energy spitting Δ_v, and the data available on the effective g-factor had been obtained from indirect considerations.[4] Observation of the oscillations of the Fermi level has made it possible to determine these quantities directly.

To determine the parameters of the spectrum, we compare the experimental curves with the dependence of the Fermi level on the magnetic field found through a numerical solution of the equation

$$\frac{eH}{ch}\sum\int_0^\infty D(\varepsilon - E_1, \Gamma)\, f(\varepsilon, E_F, T)\, d\varepsilon = n_s,$$

where $D = (\Gamma/\sqrt{\pi})^{-1}\exp[-(\varepsilon - E_i)^2/\Gamma^2]$ incorporates the broadening of the Landau levels in a real sample, $f(\varepsilon, E_F, T)$ is the Fermi distribution function, and $E_i = \hbar\omega_c(N + 1/2) \pm (g\mu_B H/2) \pm (\Delta_v/2)$, where Δ_v is the valley splitting, g is the g-factor, and ω_c is the cyclotron frequency. The parameter Γ is chosen in the course of the calculation by fitting the calculated function to the experimental results.

Figure 2a shows the behavior of $\Delta_v(H)$ (determined on the basis of the transitions $\nu = 3,5,7, \ldots$, which are seen at temperatures lower than during the recording of the curves in Fig. 1). We see that Δ_v, if it depends on n_s at all, does so extremely weakly (in disagreement with the theory[4]) but does depend on H. The values found by Köller[5] and Kawaji *et al.* (cited in Ref. 4) agree well with our data when they are plotted as a function of H.

Figure 2b shows that n_s dependence of the maximum value of the g-factor found from the change in the Fermi level at the transitions $\nu = 2,6$ (it is assumed here that Δ_v is independent of n_s). Also shown in Fig. 2b are the values of $g_{\min}$ found from the $\nu = 4,8$ transitions with the value[4] $m^* = (0.21 \pm 0.01)m_e$. The dashed lines correspond to the boundaries of the possible range of $g_{\max}$ according to Ref. 6. We thus see proof of the oscillations in the spin splitting which have been predicted theoretically.[4] We note, however, that this theory predicts that the amplitude of the oscillations of the g-factor will be a very strong function of the electron mobility. The samples used in Ref. 6, on the other hand, had a mobility one-third that in the present experiments, so that the approximate agreement of the results casts doubt on the predictions of Ref. 4.

An extrapolation of the value of Δ_v and of the spin splitting to $H = 0$ shows that both the valley splitting (with $\Delta_v \sim 2$ K) and the spin splitting ($\Delta_s \sim 4$ K) (apparently due to a disruption of the inversion symmetry of the crystal by the presence of a surface) persist at a zero field.

In summary, this study of the variations in the chemical potential in a magnetic field has yielded realistic values of the energy splittings in the spectrum of electrons in a magnetic field without appeal to theoretical models. The results pose some new questions for the theory.

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