# 10-5 INVITED: Electron Transport in Silicon Surface Inversion Layer

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Properties of electrons at room temperature in silicon surface inversion layer and physical mechanisms determining carrier mobility are discussed here.

1. Comparison of Classical Diffuse Scattering Theory with Experimental Results.[1]

To avoid the error due to carrier trapping at the interface, Hall mobility was measured instead of conductivity mobility and compared with the classical diffuse scattering theory without assuming constant electric field perpendicular to the interface, and the fairly good agreement was found. An example of results is shown in Fig. 1. However this agreement does not mean the effect of quantization of electron motion normal to the interface is not so significant at room temperature.

2. Surface Quantization at Room Temperature

Effects of surface quantization to interface carrier mobility at room temperature were pursued from various viewpoints. One of them is mobility anisotropy study with respect to the effective mass anisotropy for the two-dimensional carrier.[2][3] Figure 2 shows an example of them. Another work is magnetoresistance study on electrons at the interface inversion layer. The dependence of the magnetoresistance on the glancing angle of magnetic field to the interface reveals whether electrons are in the electrical quantum limit or not,[4] the dependence is shown in Fig. 3 in terms of the gate voltage. Anisotropic channel conductivity on the (110) surface of silicon[5] also indicates the surface quantization of electrons at room temperature. Experimental results are illustrated in Fig. 4.

3. Scatterers for Carriers in the Interface Invession Layer

Magnitude of the magnetoresistance reflects the energy dependence of scattering relaxation time of carriers, as indicated in Table 1.[4] Experimental results, shown in Fig. 5, indicate that the relaxation time is inversely proportional to the square root of the carrier energy. On the other hand, effects of scattering due to bulk phonons[6] and surface phonons,[7][8][9][10] and surface roughness[11][12] on carrier mobility have been discussed. The relation of the magnetoresistance experiments to the proposed scattering mechanisms are still not completely understood.

4. High Field Effect.

In addition to the velocity saturation[13], differential negative resistance was found in the output characteristic of MOS field effect transistor at 4.2°K.[14] Since the differential negative resistance appears even for MOSFET with (111) surface, this is not simply due to the electron transfer from a low effective mass valley to heavy effective mass valleys.

Several mechanisms are proposed[15][16][17] and discussed.

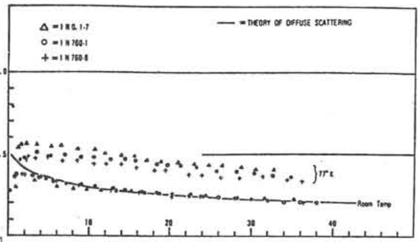

Fig 1

Table I. Galvanomagnetic coefficients. (Theoretical)

| Surface orientation | $\tau$ | $\tau \propto E$ | $\tau \propto E^{1/2}$ | $\tau$=const. | $\tau \propto E^{-1/2}$ |
|---|---|---|---|---|---|
| | Scattering | Unscreened Coulomb (high energy)[4] | Unscreened Coulomb (low energy)[4,6] | Acoustic phonons[7] | Rigid core[28] |
| (111) | $s_I$ | 1.00 | 0.66 | 0.50 | 1.36 |
| | $r$ | 1.00 | 0.75 | 0.67 | 0.85 |
| (100) Lower | $s_I$ | 0.33 | 0.10 | 0 | 0.57 |
| | $r$ | 1.50 | 1.13 | 1 | 1.27 |
| (100) Upper | $s_I$ | 1.42 | 1.01 | 0.82 | 1.86 |
| | $r$ | 0.82 | 0.62 | 0.55 | 0.70 |

$s_I=(\mu_H^2B^2)^{-1}(\Delta\rho/\rho_0)$ and $r=\mu_H/\mu_e$ calculated for the case of classical statistics. For the degenerate case, see the values in the third column ($\tau$=const.). For the isotropic case, see the values in the second row ((100) Lower).

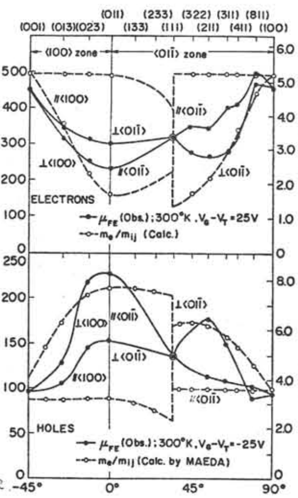

Fig 2

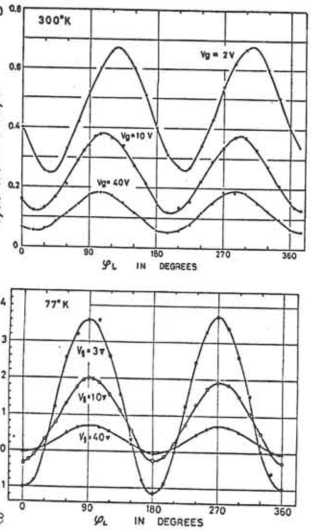

Fig 3

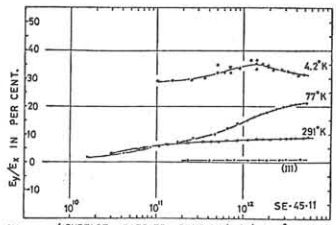

Fig 4 (SURFACE CARRIER DENSITY)$\cdot r^{-1}$ cm$^{-2}$

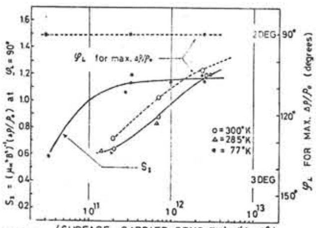

Fig 5 (SURFACE CARRIER DENSITY)$\cdot r^{-1}$(cm$^{-2}$)


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