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SURFACE QUANTUM TRANSPORT IN MOS STRUCTURE ON TELLURIUM

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The existence of an accumulation layer at the interface tellurium-tellurium dioxide (MOS structures) or at the surface of a crystal after the etching of the sample was found previously[1,2]. Due to the confinement of carriers in a narrow region, quantization of the energy of the carriers occurs[3].

We report in this paper the study by transport phenomena of the quantized carriers gas at the interface Te-TeO_2 in the plane [0001].

The samples are cut from undoped or doped single crystals of tellurium (10^{14}-$10^{16} cm^{-3}$) and are chemically polished. Samples are then anodically oxidized ; the thickness of the TeO_2 layer is about 2000 Å. The main advantages of this oxide are :

- a high dielectric quality (breakdown occurs for fields larger than 2 10^6V/cm).
- a high permittivity (ε TeO_2 = 21 ; ε Te = 53).
- a uniform coating of the crystal : we have to remember here that tellurium has a negative expansion coefficient, restricting strongly the choice of the deposited material.

Measurements (field effect conductivity, magnetoresistance, capacitance..) are made in a standard cryostat for a superconducting coil at 4.2°K and at lower temperature.

Figure 1 shows the variations of the magnetoresistance for a non-degenerate crystal ($t = 10^{14} cm^{-3}$). One observes Shubnikov-de Haas type oscillations. It appears more clearly on the second derivative of the resistance versus the applied magnetic field (Figure 2). The two curves correspond to two different bias applied on the field plate, and the shift of the minima positions proves that we are dealing with a surface effect. An important beat of three kinds of oscillations of different periods occurs. It means that three sub-bands are involved in the conduction process. Another interesting measurement is the dependance of the amplitude of the oscillations with temperature and magnetic field.

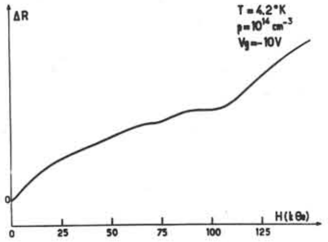


Figure 1

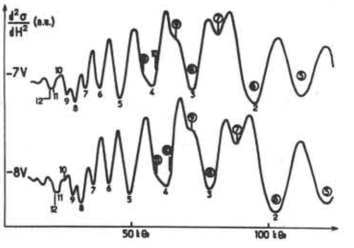


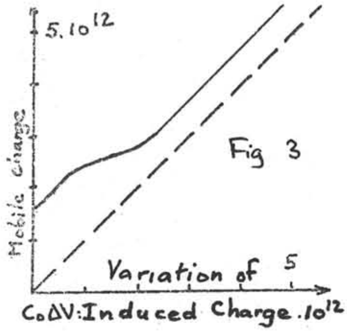
Figure 2

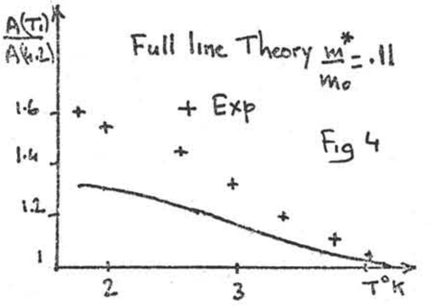
From the results we arrive at the following conclusions :

1) It is possible to obtain a strong accumulation layer at the surface of tellurium $P_S \simeq 10^{13} cm^{-2}$. At least three sub-bands contribute to the conductivity in the surface region. Such a large number of electric sub-bands has never been reported until now.

2) A first comparison with a theoretical model based on the C. Duke analysis[4] shows a discrepancy of about 15%. An improvement of the model is under way taking into account the complex valence band parameters.of tellurium.

3) From the periods of the oscillations, we are able to determine with good accuracy the number of mobile carriers, so we evaluate the trapping at the interface and the presence of a fixed charge, as shown on Figure 3.





4) From the temperature and magnetic field dependences of the amplitude of the oscillations, we conclude that there is an increase of the effective mass of 25% for the carriers in the surface region. It may correspond to the effect of the non-parabolicity of the valence band (Fig.4). The Dingle temperature T_D has a lower value than in the bulk of a doped material ($p \sim 10^{18} cm^{-3}$), giving nearly the same Shubnikov-de Haas oscillations ($T_D \simeq 2°-3.5°K$, $T_{D\ bulk} = 30°$ to $40°K$). It shows that, in the bulk, the scattering on impurities is the dominant process.

References

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4. C.B. Duke, Phys. Rev., 159, 632 (1967).