THE GALVANOMAGNETIC PROPERTIES OF SHORT-PERIOD SnTe/PbTe SUPERLATTICES

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(001) oriented SnTe/PbTe superlattices (SLs) with the period in the range of 9-60 nm are grown. The temperature dependence of the conductivity, the Hall coefficient and the magnetoresistance anisotropy are investigated in the SLs in the temperature range of 1.5-300 K and magnetic fields up to 1.5 T. The SLs are of n-type with the apparent electron concentration in the range of 10^{19}-10^{20} cm^{-3}. The type II band ordering is concluded for the SLs. Below 6 K the SLs exhibit superconductivity . The superconductivity is suggested to have a local character and to be associated with the strained pseudomorphic SnTe layers.

1. Sample Preparation and Structure

(001) oriented SnTe/PbTe superlattices (SLs) are grown by evaporation of PbTe and SnTe in an open system at pressures of ~5×10^{-5} mbar. The substrates for the SLs consist of 20 nm thick PbS films on glass or mica supports. The PbS films are epitaxially grown on (001) KCl crystals. The crystals are then dissolved and the films planted on glass or mica supports. Thus the prepared substrates have the advantage over KCL substrates, that the effect of steps formed on the KCl surface is avoided. During the SL growth the substrates are kept at T=350°C. The SL periods are determined from the satellite reflections of x-ray diffraction patterns. Fig.1 shows a typical pattern obtained. The thickness ratios of the PbTe layer to the SnTe layer are between 1 and 3. Thus, the SnTe layers are more highly strained, being thinner. Electron microscope investigations reveal that the critical thickness of the SnTe layers for the formation of misfit dislocations is about 10 nm. In thicker layers irregular dislocation lattices are observed.

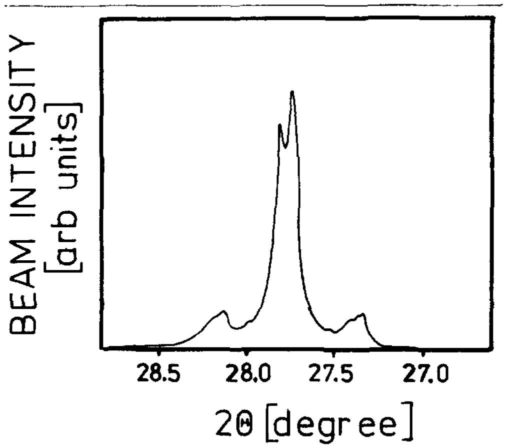

Fig.1. The x-ray diffraction pattern of superlattice No294.

2. Galvanomagnetic Properties

The temperature dependence of the conductivity σ, the Hall coefficient R_H and the magnetoresistance anisotropy are investigated in fourteen SLs in the temperature range T=1.5-300 K and in magnetic fields up to B=1.5 T. Basic

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parameters of the representative SLs are given in Table 1.

Table 1
Basic parameters of the SnTe/PbTe SLs.

SL	D	d	N	n_a	μ
297	9.0	3.0	17	15	55
294	9.0	3.0	30	3	325
296	10.0	3.0	30	2	100
291	16.5	5.5	11	5	880
292	22.0	10	10	2	470
293	33.0	11	14	5	105

In the table SL is the superlattice number, D is the SL period in nm, d is the width of the SnTe layer in nm, N is the number of the periods and n_a and μ respectively are: the apparent[5] electron concentration and the mobility determined from the Hall measurements carried out at 77 K.

The Hall measurements are also performed on single-films of PbTe and SnTe of thicknesses between 200-900 nm and on single-heterojunctions made of those films. The PbTe films are n-type with electron concentration in the range of $n=(1-10)\times10^{18}cm^{-3}$ and a room temperature electron mobility $\mu=200-800$ cm^2/Vs. The SnTe films are p-type with hole concentrations $p=(2-6)\times10^{20}cm^{-3}$, and a room temperature hole mobility is $\mu=100-400$ cm^2/Vs. The single-heterojunctions are p-type in contrast to the SLs which are n-type.

Fig.2 shows the dependence of conductivity on temperature $\sigma=\sigma(T)$, in the SLs. Between 5 K and 100 K, σ depends weakly on T and above 100 K it exhibits an anomalous maximum of unknow origin. The dependence of R_H on T (not shown) is a mirror reflection of the dependence of σ on T, i.e. $R_H(T)$ exhibits a minimum above 100 K. However, after several subsequent measurements, the anomaly usually vanishes and both σ and R_H become virtually independent on T. Some SLs do not exhibit the anomaly. Below 5 K the SLs with D<30 nm show a transition to superconductivity (SL №291) or a marked increase in σ, whereas the SLs with D>30 nm do not show any increase in σ. The SL magnetoresistance at T>6 K is described by the classic formula

$$R(B)/R(0) = 1 + const(\mu B)^2. \quad (1)$$

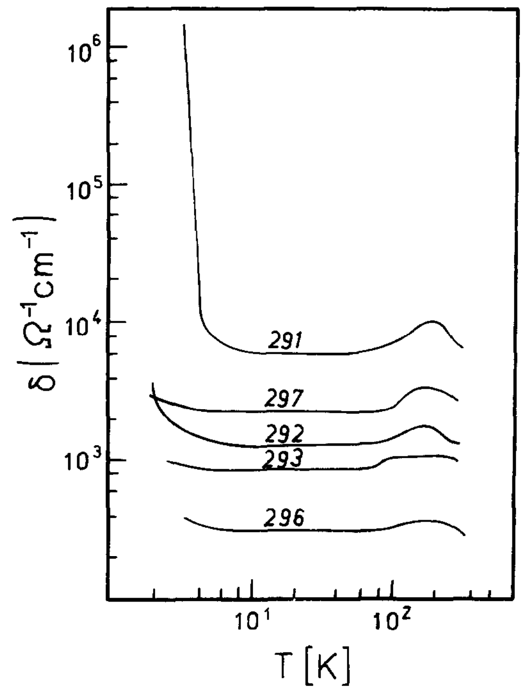

Fig.2. The temperature dependences of the conductivity of the superlattices listed in Table 1.

For the current along the (100) direction the transverse magnetoresistance is considerably larger than the longitudinal, for example at B=0.5 T, we have $R^{\parallel}(B)/R^{\perp}(B)\approx 0.2$. Below 6 K the magnetoresistances deviate from the quadratic dependence on B and become strongly dependent on T. This is shown in Fig.3. The deviation for the SLs with D>30 nm is, however, considerably weaker. In the considered temperature range the Hall coefficients of the SLs are independent on B.

3. Discussion and Conclusions

We have prepared and investigated short-period SnTe/PbTe SLs. The preparation method used leads to a high hole concentration p in SnTe films and to a high electron concentration n in PbTe Films. The relatively high substrate temperature during the SL deposition should result in diffusion at the interfaces [1]. The estimated width of the interdiffused interface PbSnTe alloy region is about 1 nm. The apparent electron concentrations in the SLs

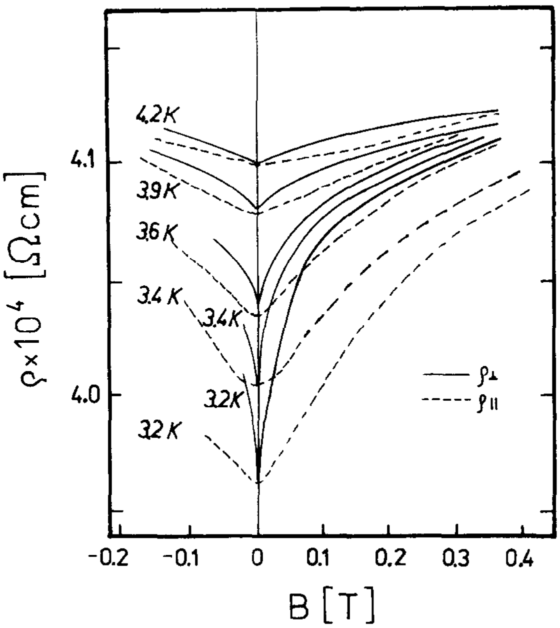

Fig.3. The transverse and longitudinal magnetoresistance of superlattice No297 at various temperatures.

$n_a = 10^{19} - 10^{20} cm^{-3}$ are much higher than those observed so far [1,2]. The superlattice concentration n_a is about 10 times the concentration n in the single PbTe films. Hence, it is concluded, that there is a transfer of electrons from the valence band of the SnTe layers to the conduction band of the PbTe layers. This confirms the proposed in Refs.[1,2] type II ordering of bands in SnTe/PbTe SLs, and contradicts the ordering proposed in Ref.[6].However, in the Type - II ordering the Hall coefficients of the SLs should be markedly dependent on T and B [1,2]. The lack of such dependences in our SLs is not understood and needs further studies.

The superconductivity (SC) of SnTe/PbTe SLs observed in Ref.[3] was suggested to be associated with the PbTe layers, in particular with lead precipitates. Our electron microscope studies do not reveal such precipitates. As seen in Fig.2 transitions to SC occur only in the very short-period SLs (D<30 nm) having highly strained SnTe layers,and do not occur in the longer-period SLs (D>30 nm) in which the strain is released by the generation of misfit dislocations. The lack of sharp SC transitions in SLs No 297 and 296 is not understood but is believed to be due to some SL structural imperfections, as they have very thin SnTe layers.

The small longitudinal magnetoresistance shows, that the conduction has a quasi two-dimensional character. The deviation of the magnetoresistance at low temperatures from the formula of eqn(1), shown in Fig.3, we ascribe to electron scatterings by SC fluctuations, as described by the Maki-Thompson model [4]. Since the deviation from the quadratic dependence on B is much smaller in the longer-period SLs and since these superlattices have many misfit dislocations and exhibit no SC transition, we gather that they have small SC regions locaized probably in the less-strained portions of the SnTe layer within the dislocation grid. Thus we suggest that the SC has a localized character and is associated with the strained SnTe layers. Only when the SC regions are large enough to form SC paths the SL as a whole shows a sharp SC transition.

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