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Electron Effective Mass of SnO_2

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The electron effective mass of SnO_2 has been measured with thin films[1)~3)] and natural crystals[4)]. However, the reported values have been scattered between 0.1 and 1.0 m, and the reliable value is not yet obtained. We wish to report here the value of the electron effective mass estimated from the measurements of Hall effect and thermoelectric power with n-type SnO_2 single crystals prepared by the vapor reaction method[5)].

The temperature dependence of the Hall mobility is presented in Fig. 1. T^{-2} dependence is observed above 160°K. Since the power -2 is rather close to $-3/2$, it is likely that acoustical phonons are most important in the electron scattering process for this temperature region. The deviation from the $T^{-3/2}$ dependence suggests that optical phonons also contribute to the scattering process to some extent.

The carrier concentration data shown by circles in Fig. 1 were calculated from the Hall coefficients, assuming that $\mu_H/\mu=3\pi/8$. The sample was found

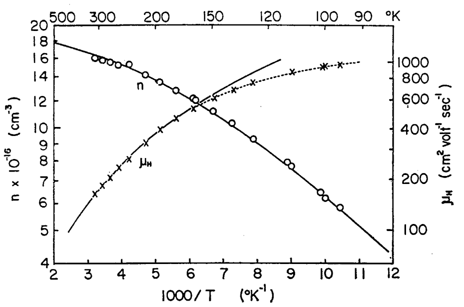

Fig. 1. Temperature dependence of the Hall mobility μ_H and of the carrier concentration n for a SnO_2 single crystal. The experimental data are indicated by crosses for μ_H and by circles for n. The solid line for μ_H represents $\mu_H=\text{constant}\times T^{-2}$. The solid line for n represents the calculated curve of eq. (1) with $N_D=1.95\times10^{17}$ cm^{-3}, $N_A=1\times10^{16}$ cm^{-3}, $m^*=0.40m$ and $E_D=0.024$ eV.

to be nearly in the carrier saturation region over the whole temperature region investigated. Extraporating the measured points to $T=\infty$, (N_D-N_A) was estimated to be $(1.85\pm0.05)\times10^{17}$ cm^{-3}, where N_A and N_D are the acceptor and donor concentrations, respectively. In analyzing the carrier concentration data, the following well known formula for the electron concentration n derived from nondegenerate statistics was used.

$$n(n+N_A)/(N_D-N_A-n)=(N_C/g)\exp(-E_D/kT)\,. \tag{1}$$

Here $N_C=2(2\pi m^*kT/h^2)^{3/2}$, m^* being the density-of-states mass, and E_D is the ionization energy of the donor centers. The donor degeneracy factor g was assumed to be 2, corresponding to the simple spin degeneracy. Taking the experimental error in to account and assuming that $N_A\leq N_D/10$, it is possible to satisfactorily fit the data with eq. (1) using the values of $N_A=(1\pm1)\times10^{16}$ cm^{-3}, $N_D=(1.75\pm0.15)\times10^{17}$ cm^{-3}, $m^*=(0.41\pm0.10)m$ and $E_D=0.024\pm0.004$ eV, as is seen in Fig. 1.

Measurements of thermoelectric power Q at room temperature were also performed. The data were analyzed with the familiar formula,

$$Q=-(k/e)[(5/2-s)+\ln(N_C/n)]\,, \tag{2}$$

where s is the scattering factor. The contribution of the phonon-drag effect to the thermoelectric power was neglected in eq. (2), since the temperatures are fairly high. Using the values of n obtained from the Hall effect measurements and assuming that $s=-1/2$ which corresponds to the acoustical phonon scattering, the density-of-states mass was found to be $0.33m$. This agrees with that obtained above from the analysis of the carrier concentration within the experimental error.

It is concluded from our experiments that the electron effective mass of SnO_2 lies near $0.35m$.

More detailed study on the electron effective mass of SnO_2, including free carrier absorption and reflection measurements, is now in progress.

References

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