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HALL-EFFECT STUDIES IN DEPOSITED CdS THIN FILMS

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Hall-effect measurements taken as a function of temperature have been performed as a portion of an investigation into the electrical properties of deposited thin films of CdS. Films have been obtained with room-temperature Hall mobilities from 2 to 12 $cm^2 V^{-1} sec^{-1}$, and with resistivities ranging from 10 to 10^4 ohm cm. The resistivity variation resulted only from differences in fabrication technique, and no intentional impurities were added to the films. The temperature variation of the mobility is markedly different from that reported in conventionally-grown single-crystal CdS. It is believed that this difference may be due either to interparticle barriers between crystal domains or to scattering by impurities and imperfections, which is comparable with or dominant over thermal scattering in the temperature range of investigation.

The CdS films were fabricated using the method described by Zuleeg and Senkovits[1], and ranged in thickness from 0.3 to 3μ. The Hall samples were 1.75 cm in length and 0.5 cm in width, and were condensed from the vapor phase on glass microscope slides. The resistivity of the CdS powder used to form the films was of the order of $10^8 \Omega$ cm. This value was measured by monitoring the resistance of a specified length of the material compressed into a ceramic cartridge. The powder was of the ultra-high-purity grade purchased from the Eagle Picher Company.

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Measurement Technique

The measurements reported here were performed with dc instruments using a single Hall electrode and an external low-resistance nulling potentiometer as described in Putley[2]. This technique was subject to appreciable experimental error for samples having resistivities much in excess of 5000 Ω cm. The Hall samples were placed in an evacuated DeWar vessel having a liquid nitrogen chamber in thermal connection with the copper sample holder. Temperatures higher than the liquid-nitrogen value were obtained by heating the copper mounting block with 2 attached power resistors. Accurate control of the sample temperature between 150°K and 425°K was possible by this means. Sample thickness was obtained using a Reichert microscope with a Nomarski polarization-interferometer attachment. The entire system was calibrated by observing the Hall effect in single-crystal samples of Ge and CdS and by comparing measurements made on these samples with published data.

Results

The most striking behavior observed in all the films studied was an exponentially-increasing Hall mobility as temperature increased. This variation is evident in Fig. 1, which gives mobility-temperature variations for 6 samples studied. These 6 samples varied greatly in the mode of their fabrication and in their physical and electronic properties as can be seen in Table I.

Both the Hall coefficient and resistivity were also approximately exponentially-variant as can be seen in Fig. 2 and Fig. 3. Table I lists the apparent activation energies for mobility E_μ, Hall coefficient E_R, and resistivity E_ρ as deduced from the measured data. Since the Hall coefficient is a measure of the reciprocal of the free-charge density, the sum of the activation energies for the mobility and the Hall-coefficient should equal the activation energy of the resistivity, as is observed.

Discussion

The observation of an exponential dependence for Hall mobility on temperature in deposited CdS films was first reported by Berger[3]. Such a dependence has also been found in deposited films of PbS, and following the analysis of Petritz[4], it is often ascribed to scattering at the boundaries between the small crystallites which make up the film. There is reason to doubt this hypothesis chiefly because of the near independence of the observed Hall-mobility value on crystallite size. This view is corroborated by Berger[3]. Work is now going on in this laboratory to ascertain whether or not the observed mobility dependence is not resultant from the large deep-trap densities that are known to characterize these films. This information is being sought through photo-Hall effect measurements, and through thermally-stimulated trap emptying studies.

References

1. R. E. Zuleeg and E. J. Senkovits, Electrochem. Soc. Meeting, Pittsburgh, Pa., Apr. 1963, Abstract 95.

2. E. H. Putley, The Hall Effect and Related Phenomena, Butterworth and Co., London (1960).

3. H. Berger, Phys. Status Solidi, 1, p. 739; 1961.

4. R. L. Petritz, Phys. Rev., 104, p. 1508; 1956.

TABLE I.

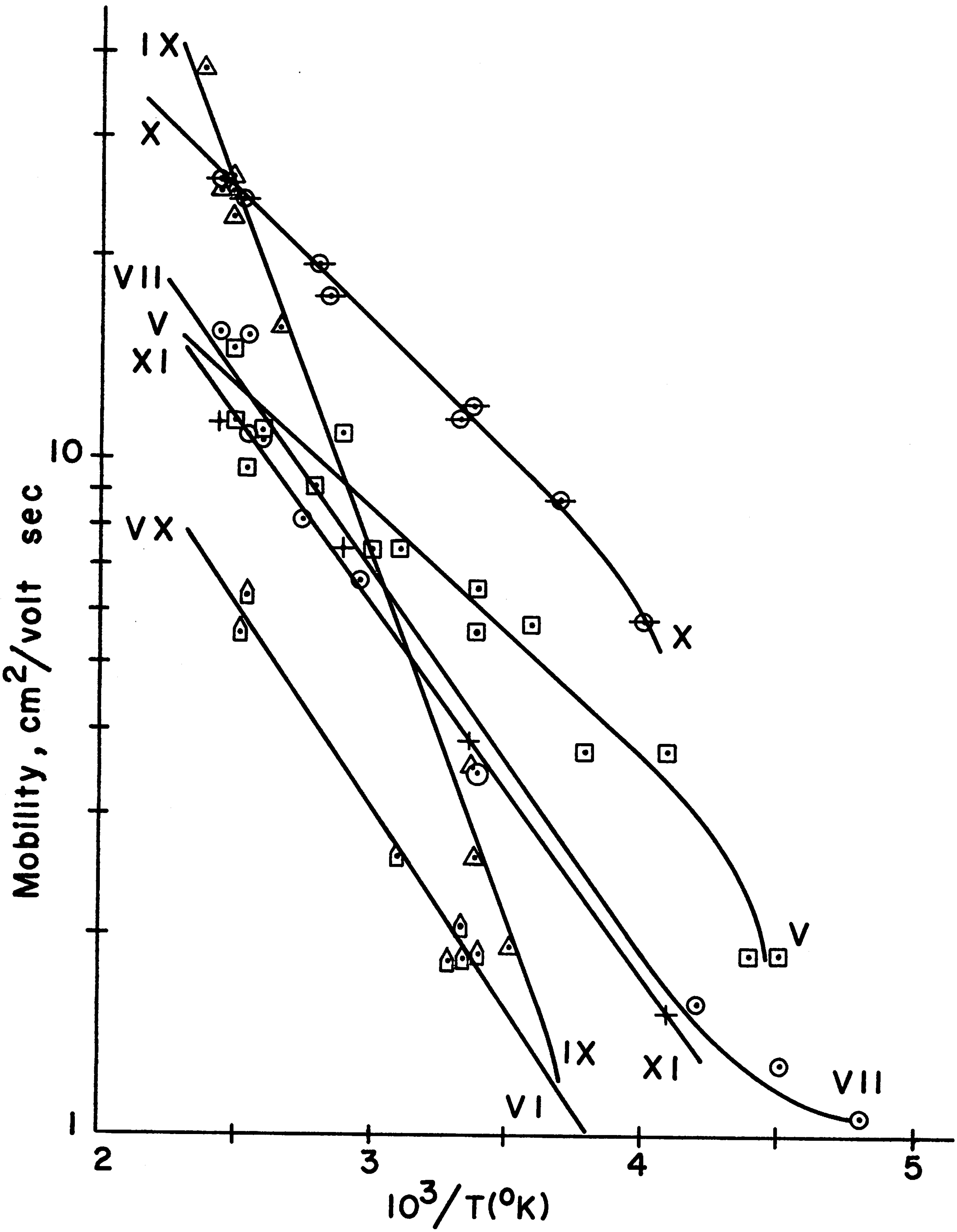
Sample	Resistivity (Ωcm) (300K)	Hall Mobility (cm^2/Vsec) (300K)	E_R (eV)	E_μ (eV)	E_ρ (eV)	Source T (^oC)	Substrate T (^oC)	Processing	Color
5	32	6	.13	.07	.21	--	23	360^oC H_2 bake	yellow
6	6	2	.06	.12	.18	--	23	None	black
7	24	4.4	.07	.12	.18	880	100	None	orange
8	10,000	--	--	--	.32	820	200	None	yel-or.
9	270	3.2	.05	.20	.25	750	200	None	yel-or.
10	1900	12	.35	.07	.42	760	140	None	yel-or.
11	650	4	.12	.10	.22	730	160	None	yel-or.

Figure Captions

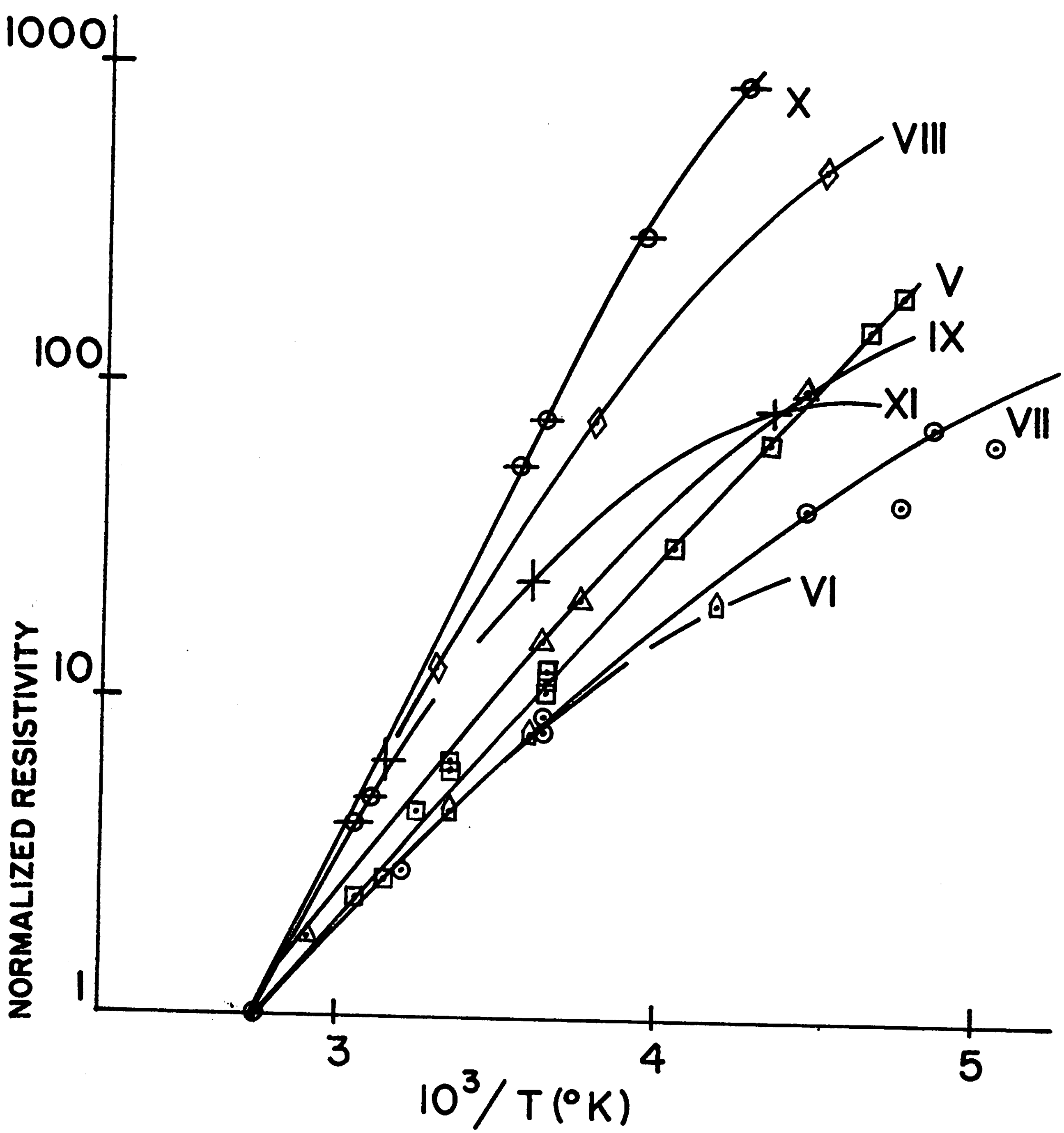
Fig. 1 Temperature dependence of Hall mobility μ_H for CdS films.

Fig. 2. Temperature dependence of the resistivity of CdS films. The ordinate is normalized at $400^{\circ}K$.

Fig. 3. Temperature dependence of the Hall constant R_H for deposited CdS films. The ordinate is normalized at $400^{\circ}K$.

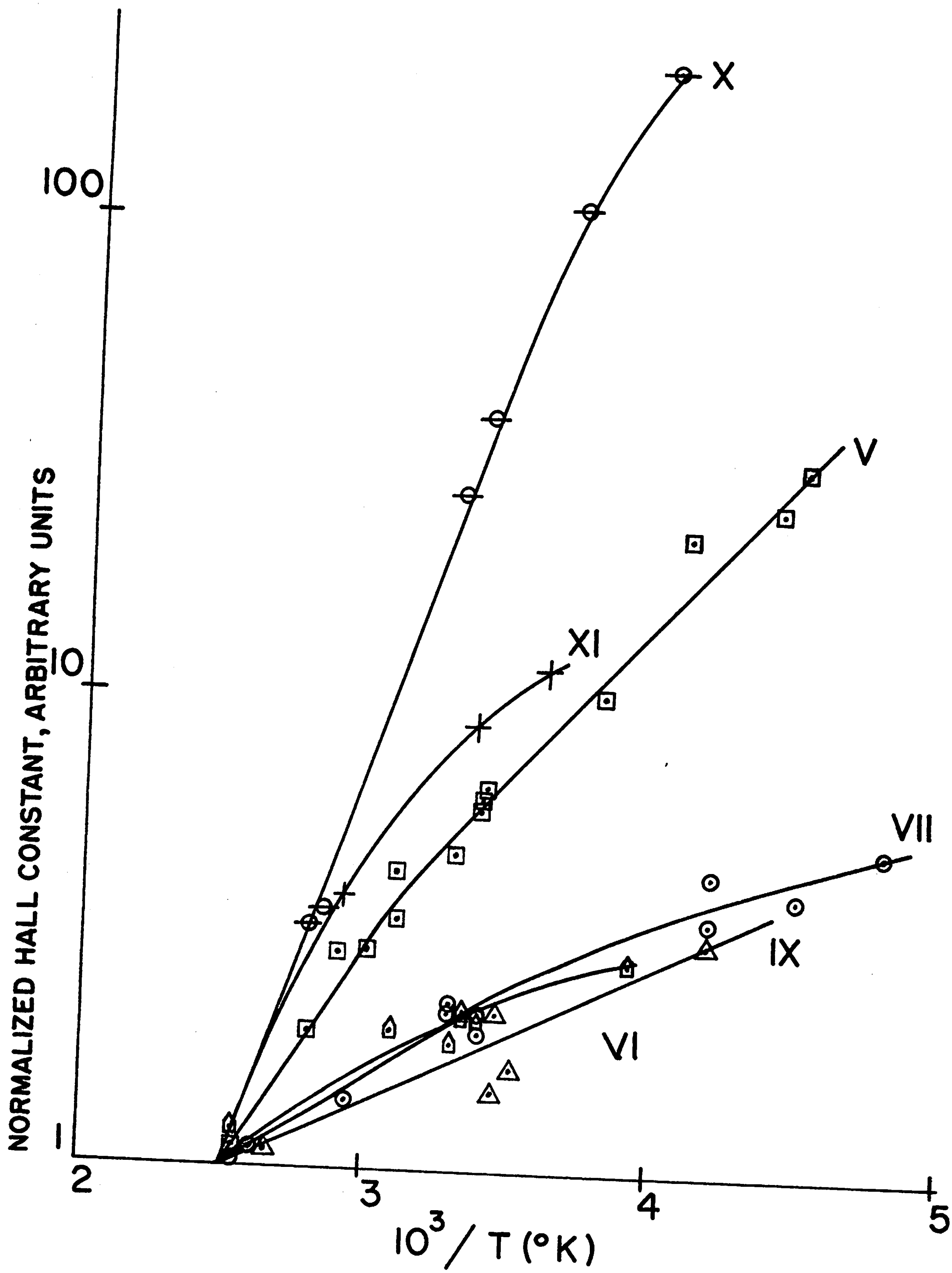


Mobility, cm²/volt sec
10³/T(°K)
10
1
2
3
4
5
IX
X
VII
V
XI
VX
VI



1000
100
10
1
NORMALIZED RESISTIVITY
3
4
5
$10^3/T(°K)$
X
VIII
V
IX
XI
VII
VI

Fig. 2



X
100
V
XI
10
NORMALIZED HALL CONSTANT, ARBITRARY UNITS
VII
IX
VI
1
2
3
4
5
10³ / T (°K)