THE DIELECTRIC CONSTANT OF THE LEAD SALTS

by

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From the mobility data of the lead salts, Allgaier and Scanlon have suggested rather large static dielectric constants, ϵ_o, of these salts[1]. Two recent works have reported ϵ_o of PbS of 140 ± 20[2] and 174.4[3] from far infrared optical transmission and reflectivity data on thin single crystal films. From microwave measurements we found ϵ_o of PbS was 161.5 ± 0.6. The experiment exploited the fact that a dielectric plate or window in a waveguide has a voltage-standing wave ratio (VSWR) minimum whenever the thickness of the plate is n half-wavelengths[4], thus

$$\epsilon_o = (\frac{\lambda}{nt})^2 \tag{1}$$

where t is the thickness of the crystal, λ the wavelength, and n the number of half-wavelengths traversing the sample in distance t.

Samples used in this experiment were natural crystals of PbS (Galena) from Colorado[5]. Since these crystals have conductivities of the order of 0.2 $(\Omega\text{-cm})^{-1}$, precise determination of the VSWR can be made, and at the same time,

no skin depth problem at 25 Gc/sec. was encountered.
Table 1 gives a spectroscopic impurity analysis of the
samples. Three samples were lapped or lapped and etched
to thicknesses of 3.77, 3.67, and 3.25 x 10^{-2} cm., and
their respective dielectric constants were 160.9, 161.3,
and 162. The average value of ϵ_o, therefore, is 161.5 ± 0.6.
If this value is used to calculate the transverse optical
frequency, ν_t, according to the Lydane, Sachs, Teller (LST)
relationship,

$$\frac{\epsilon_o}{\epsilon_\circ} = \left(\frac{\nu_1}{\nu_t}\right)^2 , \qquad (2)$$

with $\epsilon = 16.8$ [6], and $\nu_1 = 212$ cm.$^{-1}$ [7], a value of $\nu_t =$
220 cm.$^{-1}$ is obtained. This should be compared with Geick's
value of 212 cm.$^{-1}$ [2] and Zemel's value of 250 cm.$^{-1}$ [3].

In the case of PbTe, there is a large discrepancy in
the value of ϵ_o; Cochran has obtained a value for ϵ_o of 310
by the inelastic scattering of neutrons from single crystals [8],
while Watanabe obtained a value of ϵ_o less than 200 from
surface impedance measurements at 24 Gc/sec. [9]. Kanai and
Shohno gave a value of 400 from the result of capacitance

measurements on an abrupt p-n alloyed junction [10].
However, Watanabe's experiment could have some diffi-
culties arising from the large conductivity of PbTe.
This would result in a strong attenuation of the radiation
near the surface, which was experienced in our previous
measurement, similar to the one described here on natural
PbS, and leading to an erroneous result [11]. There is
also some objection to the electrode configuration used by
Kanai and Shohno. Since the results of PbS presented here
show a good agreement with the result obtained from the LST
relation, Cochran's result should be closer to the true
value. An experiment similar to the one described here on
a well compensated crystal of PbTe would be interesting.

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TABLE 1

Impurity	Percentage Detectable
Ag	0.01 - 0.1
Al	less than 0.001
Ca	" " 0.001
Cu	" " 0.001
Fe	" " 0.001
Mg	" " 0.001
Mn	" " 0.001
Sb	0.001 - 0.01
Si	0.001 - 0.01