diameters, sharing their energy with cathode atoms. The heat of vaporization is less than 1 e.v. per particle. Accordingly, in the spot microvolume, particle energies are so high that conditions resemble those of a highly compressed gas in the supercritical region more than those of the solid or liquid state. To this region electrons flow metallically, from it they are emitted thermionically. More than a superficial parallel appears to exist between steady state arc spot conditions and transient conditions encountered in experiments on wires exploded by tremendous peak currents.

This picture agrees with the experiments of Plesse[1] on the important role of metallic vapor at the cathode spot. He found, for example, that the essential characteristics of Zn, Cd, or Hg arcs could be obtained with a Ni cathode supplied with Zn, Cd, or Hg vapor, respectively, by evaporation from an oven or from the cathode of an auxiliary discharge. The vapor source could be inside or external to the cathode. Nitrogen was the gas employed.

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[1] H. Plesse, Ann. der Physik 22, 473 (1935).

Photoelastic Properties of Cubic Crystals

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The photoelastic effects in cubic crystals have been explained by Mueller[1] in terms of the anisotropy of the Lorentz-Lorenz and Coulomb forces produced by a distortion of the lattice. The contribution of the optical anisotropy of the ions was taken into account by means of phenomenological constants. This contribution was found to be negative for the few crystals for which data were available at the time, and Mueller assumed that it would also be negative for other crystals.

Additional photoelastic data have been obtained recently at this laboratory[2] which show that Mueller's conclusions concerning the optical anisotropy contribution must be modified. A summary of these and other recent data is given in Table I.

The purpose of this note is to present these results and to discuss further the significance of the optical anisotropy constant λ_0. Some qualitative relations between λ_0 and the temperature dependence of the refractive index will also be discussed.

In general, Mueller's predictions for crystals having NaCl structures are correct but his predictions of the sign of $(p_{11}-p_{12})$ for diamond and CsCl structures (thallium halides) are wrong. Assuming the correctness of the theory in evaluating the $L-L$ and Coulomb contributions, the error apparently lies in Mueller's assumption concerning the optical anisotropy contributions. For diamond which is monatomic and covalent this contribution (as measured by Mueller's optical anisotropy constants $(\lambda_{12}-\lambda_{11})$) can be unambiguously calculated using the theory and the experimental values of $(p_{11}-p_{12})$. This calculation yields $\lambda_{11}=+0.7$; $\lambda_{12}=+2.0$; $\lambda_{44}=+1.8$. The optical anisotropy contribution is positive $(\lambda_{12}-\lambda_{11}=+1.3)$ and larger than the $L-L$ contribution of -0.66. It is suggested that in the thallium halides the optical anisotropy contribution is also positive and large enough to more than compensate for the negative $L-L$ and Coulomb contributions. Such a positive contribution could result from the fact that in a CaCl structure the cation-anion bond is directed along [111], and a [100] strain alters the anion-anion distance more than the cation-anion distance. A similar effect would be expected for ZnS and diamond structures.[5]

Table I.

Crystal	$p_{11}-p_{12}$	p_{44}	p_{11}	$\rho dn/d\rho$ obs	λ_0
LiF	-0.108 (−)**	-0.064 (−)**	~ 0.02	~ 0.1	~ 0.7
NaCl	-0.043 (−)	-0.010 (−)	0.11	0.24	0.60
KCl	$+0.046$ (+)	— (−)	0.17	0.23	0.60
KBr	$+0.049$ (+)	-0.26 (−)	0.22	0.35	0.50
KI	$+0.041$ (+)	— (−)	0.21	0.43	0.50
MgO	-0.24 (−)	— (−)	~ -0.13	~ -0.4	~ 1.4
TlCl*	$+\sim 0.03$ (−)	$+\sim 0.06$ (+)	—	—	—
Diamond[3]	$+0.45$ (−)	$+0.011$ (+)	0.125	-2.62	1.5
K-Alum[4]	-0.08	-0.0056	0.27	0.53	0.06

$$\lambda_0=1-\frac{\rho(dn/d\rho)\text{obs}}{\rho(dn/d\rho)\text{calc}} \qquad \rho(dn/d\rho)\text{obs}=\frac{n^3}{6}(p_{11}+2p_{12})$$

$$\rho(dn/d\rho)\text{calc}=\frac{(n^2-1)(n^2+2)}{6n}$$

* Values for TlCl approximate.

** The signs of the photoelastic constants as predicted by Mueller are given in parenthesis.

Values for the change in refractive index with density $(\rho dn/d\rho)$ and the optical anisotropy constant for hydrostatic pressure λ_0 (corresponding to the change in molar polarizability with volume) are also given in Table I. In all cases the observed values of $\rho dn/d\rho$ were smaller than the calculated values, and in MgO and diamond the measured $\rho dn/d\rho$ is actually negative; that is, a hydrostatic pressure is found to cause a decrease in refractive index. As a result, the λ_0 values for these crystals are greater than one, indicating that the change in ionic polarizability is greater than the effect of changing the number of ions per unit volume.

Since the change in ionic polarizability with strain results from a change in the overlap of the ions, it is suggested that its magnitude depends on the amount of overlap present in the unstressed crystal and that λ_0 may be used as a measure of the amount of homopolar bonding. This is borne out by correlation with other methods of estimating homopolar bonding.

Data on the change of index with temperature are also of interest. From existing data on dn/dT it appears that for those simple crystals which contain no radicals and have small λ_0 values, the change of index with temperature is determined mainly by the density contribution $(\partial n/\partial\rho)_T \times (d\rho/dT)$; the temperature contribution $(dn/dT)_\rho$ is small, and dn/dT is negative. For crystals with large λ_0 the temperature contribution is positive and about the same order of magnitude as the positive density contribution. From these considerations one would, therefore, predict MgO to have a positive dn/dT. For ZnS, which is known to have a positive *dn/dT* and is considered to have large homopolar bonding, similar reasoning predicts that *dn/dρ* is positive; i.e., $\lambda_0 > 1$. In crystals containing radicals and in many glasses, positive *dn/dT* values are frequently obtained although their *dn/dρ* values are negative. In these materials there are effects within the radical which contribute mainly to *dn/dT* and only slightly to *dn/dρ*. A more complete treatment of these subjects will be presented in a forthcoming paper.

[1] H. Mueller, Phys. Rev. **47**, 947 (1935).

[2] Burstein, Smith, and Henvis, Bull. Am. Phys. Soc. **23** (2), 33 (1948).

[3] G. N. Ramachandran, Proc. Ind. Acad. Sci. **A25**, 266 (1947).

[4] S. Bhagavantam and S. Suryanarayana, Proc. Ind. Acad. Sci. **A26**, 97 (1947).

[5] C. D. West and J. Makas, Chem. Phys. **16**, 427 (1948) reported $+(p_{11}-p_{12})$ for two mixed thallium halides in agreement with our results. Their data also gives a $+(p_{11}-p_{12})$ and $-p_{44}$, for AgCl in agreement with Mueller's prediction for NaCl structures with small ratio of negative to positive ion polarizibilities. We do not agree with West and Makas concerning the sign of the diamond constants and believe them to be correct as given by Ramachandran.[3]

The Transistor, A Semi-Conductor Triode

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A THREE-ELEMENT electronic device which utilizes a newly discovered principle involving a semi-conductor as the basic element is described. It may be employed as an amplifier, oscillator, and for other purposes for which vacuum tubes are ordinarily used. The device consists of three electrodes placed on a block of germanium[1] as shown schematically in Fig. 1. Two, called the emitter and collector, are of the point-contact rectifier type and are placed in close proximity (separation ∼.005 to .025 cm) on the upper surface. The third is a large area low resistance contact on the base.

The germanium is prepared in the same way as that used for high back-voltage rectifiers.[2] In this form it is an *N*-type or excess semi-conductor with a resistivity of the order of 10 ohm cm. In the original studies, the upper surface was subjected to an additional anodic oxidation in a glycol borate solution[3] after it had been ground and etched in the usual way. The oxide is washed off and plays no direct role. It has since been found that other surface treatments are equally effective. Both tungsten and phosphor bronze points have been used. The collector point may be electrically formed by passing large currents in the reverse direction.

Each point, when connected separately with the base electrode, has characteristics similar to those of the high back-voltage rectifier. Of critical importance for the operation of the device is the nature of the current in the forward direction. We believe, for reasons discussed in detail in the accompanying letter,[4] that there is a thin layer next to the surface of *P*-type (defect) conductivity. As a result, the current in the forward direction with respect to the block is composed in large part of holes, i.e., of carriers of sign opposite to those normally in excess in the body of the block.

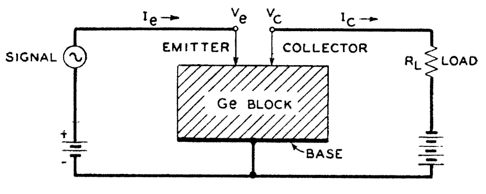

Fig. 1. Schematic of semi-conductor triode.

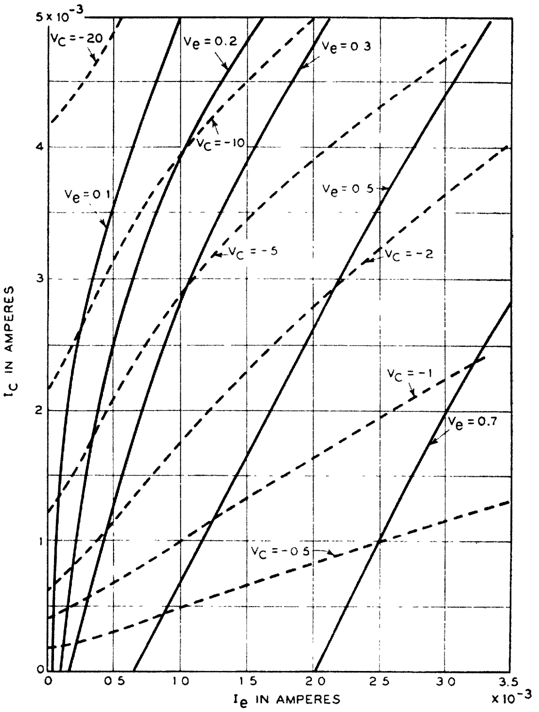

Fig. 2. d.c. characteristics of an experimental semi-conductor triode The currents and voltages are as indicated in Fig. 1.

When the two point contacts are placed close together on the surface and d.c. bias potentials are applied, there is a mutual influence which makes it possible to use the device to amplify a.c. signals. A circuit by which this may be accomplished in shown in Fig. 1. There is a small forward (positive) bias on the emitter, which causes a current of a few milliamperes to flow into the surface. A reverse (negative) bias is applied to the collector, large enough to make the collector current of the same order or greater than the emitter current. The sign of the collector bias is such as to attract the holes which flow from the emitter so that a large part of the emitter current flows to and enters the collector. While the collector has a high impedance for flow of electrons into the semi-conductor, there is little impediment to the flow of holes into the point. If now the emitter current is varied by a signal voltage, there will be a corresponding variation in collector current. It has been found that the flow of holes from the emitter into the collector may alter the normal current flow from the base to the collector in such a way that the change in collector