tinctive types, this classification apparently having little or no relation to the steady-state characteristics. Typical response curves are shown in Fig. 2. In each case the forward current between pulses was 40 milliamperes and the potential V was carried from a small positive value to -50 volts with a rise time of approximately 0.03 microsecond. Curve A represents a large class of varistors showing no appreciable effect of hole withdrawal. Curve B shows a small or moderate burst, having an exponential decay with a time constant of the order of 0.1 microsecond. In curve C, the reverse current first rises roughly in proportion to the voltage, then drops very abruptly and once more rises, after which

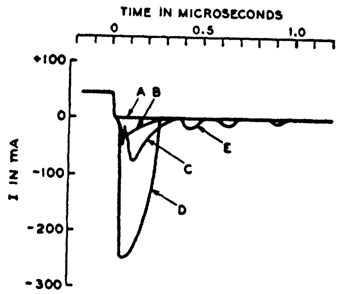

FIG. 2. Pulse study of germanium diodes.

the decay is approximately exponential. Curve D shows a curious case (not particularly rare, however) representing a momentary dissipation of over 10 watts. The decaying portion of the wave form is concave upward, reaching the zero line with a remarkably sharp discontinuity. This phenomenon may be explainable in terms of the Herring shock wave.[2] Some units represented by curve D also display "bubbles" of current (curve E). These bubbles are usually observed upon initial application of the test conditions, and commonly decrease in amplitude and vanish within five or ten seconds. The bubbles, or trains of them, recur with each applied pulse but may progress gradually toward the right or left on the time axis during their appearance.

The large bursts of power associated with these effects may be expected to change the characteristics of the units, and Mr. R. R. Blair has suggested that they may account for certain previously unexplained cases of damage to varistors in switching applications. Further studies using steep wave fronts backed by ample power appear likely to contribute to the basic understanding of semiconductors.

We wish to express our thanks to Mr. W. L. Shockley and other members of Bell Laboratories for helpful suggestions in connection with this work.

[1] W. Shockley, G. L. Pearson and J. R. Haynes, Bell Sys. Tech. J. **XXVIII**, 344 (1949).
[2] C. Herring, Bell Sys. Tech. J. **XXVIII**, 401 (1949).

The Elastic Constants of Germanium Single Crystals

W. L. BOND, W. P. MASON, H. J. MCSKIMIN, K. M. OLSEN, AND G. K. TEAL
Bell Telephone Laboratories, Murry Hill, New Jersey
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THE interest in the properties of germanium single crystals arising from their use as semiconductors and transistors has led us to make measurements of the elastic constants of two single crystals.

One crystal (sample A) was grown from the melt, and two orientations were determined approximately by x-rays. Longitudinal and shear wave measurements of velocities were made along the 100 and 110 directions by the process described in an earlier communication.[1] This process determines the velocity within about ½ percent. The longitudinal and shear-wave velocities are shown by Table I. The elastic constants are calculated from the velocity measurements using a density of 5.35. From these measurements we obtain the elastic constants (in dynes/cm²)

TABLE I. Elastic properties of sample A.

Direction of propagation	Direction of particle motion	Type of mode	Equation for velocity	Measured velocity cm/sec. $\times 10^{-5}$	Elastic constants dynes/cm² $\times 10^{-11}$
110	110	long	$v=\left(\frac{c_{11}+c_{12}+2c_{44}}{2\rho}\right)^{\frac{1}{2}}$	5.39	15.5
110	$1\bar{1}0$	shear	$v=\left(\frac{c_{11}-c_{12}}{2\rho}\right)^{\frac{1}{2}}$	2.75	4.06
110	001	shear	$v=(c_{44}/\rho)^{\frac{1}{2}}$	3.54	6.70
100	100	long	$v=(c_{11}/\rho)^{\frac{1}{2}}$	4.92	12.95
100	010	shear	$v=(c_{44}/\rho)^{\frac{1}{2}}$	3.54	6.70

$$c_{11}=12.92\pm0.12\times10^{11},\quad c_{12}=4.79\pm0.12\times10^{11},\quad c_{44}=6.70\pm0.07\times10^{11}.$$

The other crystal (sample B) was obtained by an improved method for growing pure germanium crystals[2] and a more accurate method was devised for measuring velocities for small samples.[3] Hence it was thought worth while to re-measure the elastic constants. A carefully oriented 110 section was used and the measured velocities are shown in Table II. From these values the three elastic constants are found to be (in dynes/cm²)

TABLE II. Elastic properties of sample B.

Direction of propagation	Direction of particle motion	Type of wave	Equation for velocity	Measured velocity cm/sec. $\times 10^{-5}$	Elastic constants dynes/cm² $\times 10^{-11}$
110	110	long	$v=\left(\frac{c_{11}+c_{12}+2c_{44}}{2\rho}\right)^{\frac{1}{2}}$	5.410 ± 0.005	15.660 ± 0.03
110	$1\bar{1}0$	shear	$v=\left(\frac{c_{11}-c_{12}}{2\rho}\right)^{\frac{1}{2}}$	2.751 ± 0.002	4.049 ± 0.008
110	001	shear	$v=(c_{44}/\rho)^{\frac{1}{2}}$	3.547 ± 0.003	6.730 ± 0.01

$$c_{11}=(12.98\pm0.04)\times10^{11};\quad c_{12}=(4.88\pm0.04)\times10^{11};\quad c_{44}=(6.73\pm0.01)\times10^{11}.$$

[1] Bozorth, Mason, McSkimin, and Walker, Phys. Rev. **75**, 1954 (1949).
[2] This method is described by G. K. Teal and J. B. Little in a paper to be presented by title before the Oak Ridge meeting of the Physical Society (March, 1950).
[3] This method for measuring velocities by a phasing technique was described by H. J. McSkimin, J. Acous. Soc. Am. **22**, 86 (1950).

Energies of Some Gamma-Rays from ThC″, RaC, and Na^{24}

J. L. WOLFSON
Atomic Energy Project, National Research Council of Canada, Chalk River, Ontario, Canada
February 23, 1950

PRECISE values for the energies of the gamma-rays of nominal values 2.62 Mev from ThC″, and 2.2 Mev and 2.4 Mev from RaC, have recently become desirable in order to evaluate more accurately the binding energy of the deuteron.[1,2] Several measurements of the energies of these gamma-rays have been made and the results are presented in Tables I, II, and Fig. 3. In addition some measurements of the energy of the Na^{24} gamma-ray of nominal value 2.76 Mev, performed for another purpose, are given in Table II as they may be of interest in future disintegration studies.