Since the Se^{79} is still unknown, Mr. William Low searched for a line due to $OCSe^{79}$, using a recording Stark modulation spectrometer and with the OCSe gas at dry ice temperatures. If the Se^{79} occurred naturally, it should produce a line very near that due to the $OCSe^{80}$, $v_2=2$, $l=0$ transition. No absorption attributable to Se^{79} was found, however, and since the nearby OCSe, $v_2=2$, $l=0$ line strength was about seven times noise background (at -78°C), an upper limit of one part in 10,000 may be set on the natural abundance of Se^{79}.

The design of the heterodyne spectrometer has benefited from the advice of Professor Yardley Beers. In addition, the authors appreciate the considerable help of Mr. R. H. Ellis, Jr. in construction of the spectrometer, and the interest of Mr. Paul Kisliuk who some time ago initiated work on these measurements but was not able to carry them through with the equipment then available.

* Work supported jointly by the Signal Corps and ONR.
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Resonance and Thermal Neutron Scattering in V^{51}

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A LITERAL application of the Breit-Wigner scattering theory enables one to correlate the experimental values of the resonance and thermal cross sections of V^{51}

Harris, Hibdon, and Muehlhause[1] have reported a prominent neutron scattering resonance ($\Gamma_n \gg \Gamma_\gamma$) in V^{51} at $\sim$2700 ev with a scattering resonance integral, Σ_s, of 192b. This quantity yields the coherent thermal scattering amplitude, a, via the following relations:

$$a=g(\lambda\!\!\!^{-}_0\Gamma_n/2E_0), \quad \Sigma_s=\tfrac{1}{2}\pi g\sigma_0\Gamma_n/E_0,$$

and

$$\sigma_0=4\pi\lambda\!\!\!^{-}_0{}^2=2.60\times10^6/E_0,$$

where $\lambda\!\!\!^{-}_0$=neutron wave-length at the resonance energy, Γ_n=neutron width, E_0=resonance energy, and $g=\frac{1}{2}(1\pm1/2i+1)$ is the statistical weight factor ($i=7/2$, spin of V^{51}). These relations yield the formula

$$a=\lambda\!\!\!^{-}_0\Sigma_s/\pi\sigma_0=0.555b^{\frac{1}{2}} \text{ (units of } 10^{-12} \text{ cm)}.$$

Shull and Wollan[2] have reported the coherent thermal scattering cross section, σ_{coh}, to be less than 0.1b (units of 10^{-24} cm^2). This quantity, according to the one-level Breit-Wigner formula, is given by:

$$\sigma_{coh}=4\pi|R-(g\lambda\!\!\!^{-}_0\Gamma_n/2E_0)|^2=4\pi|R-a|^2;$$

where $R=0.137A^{\frac{1}{3}}$ is the nuclear radius. For V^{51} we have $R=0.508b^{\frac{1}{2}}$ and therefore:

$$\sigma_{coh}=4\pi|0.508-0.555|^2\simeq0.03b \text{ (negative phase)}.$$

The resonance data are also in good agreement with the total thermal scattering cross section, σ_s, given by Hibdon[3] as 5.02b. This quantity can be used to determine the total angular momentum, J, of the compound state at 2700 ev. Again the one-level Breit-Wigner expression for σ_s yields:

$$\sigma_s=4\pi g|R-(a/g)|^2+4\pi(1-g)R^2,$$

from which

$$\sigma_s=5.02b \ (g=7/16 \text{ for } J=3),$$

or

$$\sigma_s=3.04b \ (g=9/16 \text{ for } J=4).$$

Preference is therefore indicated for $J=3$. One may also conclude that

$$\sigma_{max}\simeq420b \quad \text{and} \quad \Gamma\simeq780 \text{ ev}.$$

Since one resonance level determines the thermal scattering cross section so completely it appears that the next closest level, ϵ_2, from zero energy is such that $|\epsilon_2|\gg2700$ ev. Other cases of light odd-Z, even-n, isotopes which display this same level pattern are:[4-6] Na, Cl, Co, and Mn.

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Observations of the Rapid Withdrawal of Stored Holes from Germanium Transistors and Varistors

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IN the course of a study of transistor response to square pulses of applied voltage and current, the behavior illustrated in Fig. 1 was found to be typical of units employing N-type germanium. The collector current I_c is there shown as a function of time for different pulsed values of I_ϵ (emitter current) and V_c (collector voltage), applied as independent parameters. For each of the curves except the ones marked "steady state," V_c was pulsed from zero to 10 volts in the "reverse" direction (for which the point contact normally has a high resistance) for a period of one microsecond.

The bursts of collector current provoked by preceding emitter current appeared to be explainable most reasonably on the basis of a rapid gathering-in of holes[1] produced by the forward emitter current and existing within the germanium at the time of application of collector potential. This explanation suggested that the same electrode might be used first to inject holes as an emitter and then to withdraw them as a collector. When this was tried, bursts of reverse current exceeding 24 milliamperes and overloading the pulser were obtained for the same voltage pulses, which interrupted a normal forward current of only 1 milliampere. With the forward current reduced to zero, the reverse current pulses became square and only a fraction of a milliampere in height.

Using a more powerful pulse generator for examining conventional germanium varistors (diodes) of various types, we found that the response curves could be classified into several dis-

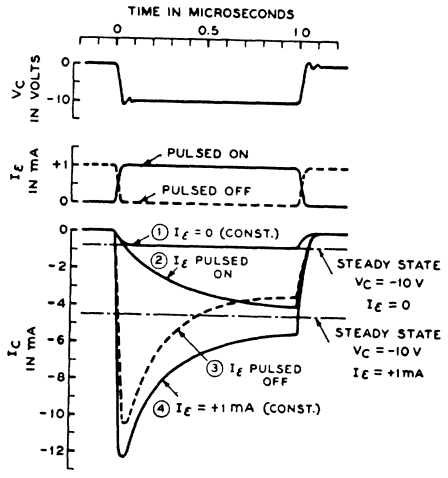

FIG. 1. Pulse study of transistors—typical wave forms.

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

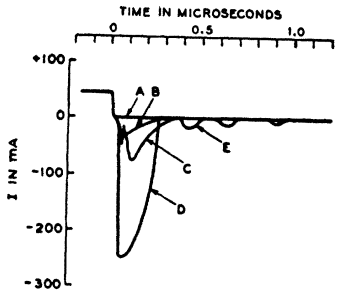

FIG. 2. Pulse study of germanium diodes.

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.

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The Elastic Constants of Germanium Single Crystals

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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

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/cm^2 $\times 10^{-11}$
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

$\frac{1}{2}$ 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/cm^2)

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

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/cm^2)

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/cm^2 $\times 10^{-11}$
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

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

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

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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.