

Table 3. Characteristics of the polymorphic transition in Ge

	Static data	Present work
Transition pressure (kb)	120-125 ^(a)	114-122
Specific volume	0.875 V_0 ^(b)	0.870 V_0 -0.880 V_0 ^(e)
Temperature (°C)	20	160 ^(c)
$\Delta V/V$	20.7% ^(b)	—
dP/dT (kb °C ⁻¹)	—	-3.1 × 10 ⁻²
ΔH (cal g ⁻¹)	—	12.5 ^(d)

(a) Ref. 10.

(b) Ref. 16.

(c) As estimated by McQueen, Ref. 13.

(d) Calculated using ΔV given by Jamieson, Ref. 16.

(e) Corrected to 20°C for comparison with static data.

one-dimensional elastic compressions which are uniquely achieved in the shock wave loading experiments. Resistivity measurements for large uniaxial elastic strains are of interest since they may be useful for confirming the theoretical calculations of KLEINMAN⁽²⁾ and GOROFF and KLEINMAN⁽³⁾ which predict the effect of a general strain tensor on the energy bands of silicon, and by inference, germanium. These measurements may also help to describe the so-called "anisotropic stress effect" observed for stressed semiconductor *p-n* junctions.⁽²³⁾

The component of the energy gap change induced by volumetric compression has been verified by hydrostatic experiments, but the component of energy gap change induced by shear strain has not been verified since large shear strain components cannot be applied statically to brittle materials such as germanium. If the germanium samples behave intrinsically for large shear strain, it is possible that the resistivity measurements under shock compression can provide a measure of the energy gap change induced by shear strain. The conditions imposed on the sample by plane-wave shock loading in the elastic range are well defined allowing all stress and strain components to be accurately evaluated. Further, since the compressions are small the process is adiabatic to a very close approximation and accurate calculations can be made of the slight temperature rise (5.6°K at 44 kb)* induced by shock wave.

* The temperature of the shocked Ge in the elastic range is computed as $T = T_0(V_0/V)^\gamma$. Gruneisen's ratio, γ , was taken as 0.725 in agreement with the data of Ref. 24.

Previous attempts to measure energy gap changes induced by shear strain have included the measurement of reflectance from Ge samples subjected to bending stress.⁽²⁵⁾ Also, piezo-resistance measurements in uniaxial stress on heavily doped germanium specimens give deformation potential determinations on the motion of individual valley minima and the valence band maximum.⁽²⁶⁾ WORTMAN *et al.*⁽²⁷⁾ have used GOROFF and KLEINMAN's⁽³⁾ theoretical predictions for silicon to predict the effect of various stress tensors on the band structure of germanium and thus the effect upon the characteristics of Ge *p-n* junctions. IMAI and UCHIDA⁽²⁸⁾ find this analysis to be consistent with their measurements of the characteristics of heavily doped Ge *p-n* junctions under uniaxial stress. Similarly, RINDNER⁽²³⁾ has applied uniaxial stress to Ge *p-n* junctions and found agreement in sign and qualitative behavior to that predicted by Wortman *et al.*

The effect of pressure on the resistivity of Ge has been extensively investigated and recently summarized in the excellent review by PAUL and WARSCHAUER.⁽²⁹⁾ The energy gap, E_g , is found to increase linearly with pressure to 15 kb at a rate of 5×10^{-3} eV kb⁻¹. From 15 kb to 30 kb the rate of increase of E_g decreases significantly. This has been shown to be consistent with the hypothesis that the minimum energy of the conduction band is shifted in *k* space. Further, effective mass changes of electrons with pressure are found to be only ½% per kb, and the mobility of electrons is found to decrease only 0.4% per kb in the absence of intervalley scattering. Considerable correlation is found between the pressure dependence of any

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3 RESULTS

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THE UNIVERSITY OF CHICAGO

PHYSICS DEPARTMENT

PHYSICS 309

LECTURE 10

STATISTICAL MECHANICS

ENTROPY

AND THE SECOND LAW

OF THERMODYNAMICS

The entropy of a system is a measure of the number of microstates consistent with the macroscopic state. It is defined as $S = k_B \ln \Omega$, where Ω is the number of microstates and k_B is Boltzmann's constant. The second law of thermodynamics states that the total entropy of an isolated system never decreases over time. This law is a consequence of the statistical nature of thermodynamics and the fact that systems evolve towards more probable states.

In a closed system, the total energy is conserved, but the entropy can increase. This is because the system evolves towards a state of higher probability, which corresponds to a higher entropy. The second law is a statistical law, meaning that it holds for large systems with a high number of particles. For small systems, fluctuations can lead to a temporary decrease in entropy, but these fluctuations are exponentially suppressed as the system size increases.

The second law has many important implications in physics and chemistry. It explains the direction of time, the irreversibility of macroscopic processes, and the existence of equilibrium states. It also plays a central role in the theory of information, where entropy is used to quantify the amount of information in a system.

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