$-4{\cdot}0$ eV/unit strain. Since the energy gap change due to the dilatational component has been evaluated to be $+3{\cdot}7$ eV/unit strain,* the shear strain contribution is $-7{\cdot}7$ eV/unit strain. This is a factor of $1{\cdot}85$ smaller than the theoretical value of $-14{\cdot}29$ eV. Thus, this measurement on Ge agrees with the sign and order of magnitude of the theoretically predicted change for Si.

Although the agreement given above is satisfactory considering the complexity of the problem, somewhat better agreement is achieved by a more detailed examination of the data. The experiment at a strain of $1{\cdot}36\%$ is well below the elastic limit and therefore in a stress region where mechanical relaxation effects are unlikely. The resistance–time record, however, exhibits an increasingly greater downward slope rather than the constant slope expected from the analysis. The curvature is more pronounced early in time and thus is not that expected from the stress unloading behavior from the lateral edge of the sample. Thus, the most likely interpretation of the nonlinear behavior is that equilibrium of carriers is not fully established and that relaxation times are of the order of 10^{-7} sec. The observed resistive behavior tends toward a constant slope late in time; hence, to establish a value for the equilibrium resistivity, the slope of the resistance–time record for late times is extrapolated for full wave transit time.† This yields a resistivity which gives a value of δE_g of $5{\cdot}3$ eV per unit strain. This value of δE_g gives a shear strain contribution for [111] one-dimensional strain of $9{\cdot}0$ eV per unit strain which is a factor of $1{\cdot}6$ smaller than the theoretical value for silicon. Thus, it appears that our best value for the [111] shear strain contribution is 60% lower than that predicted for Si. Considering the uncertain nature of the assumptions concerning the transport properties of the strained Ge and the unknown applicability of the theoretical analysis to Ge, the agreement is considered to be satisfactory. However, further interpretations seem in order.

Results of the extensive work which has been accomplished with hydrostatically strained Ge furnish a comparative background which hopefully might have relevance to the analysis of the current work. However, several major differences exist between the band structure of hydrostatically strained Ge and Ge under [111] one-dimensional strain. As indicated in Fig. 6, the conduction band structure for [111] one-dimensional strain is much simplified. The $L_1(111)$ level is lowered considerably, while the $L_1(1\bar{1}\bar{1})$, $L_1(1\bar{1}1)$ and $L_1(11\bar{1})$ levels are raised at a rapid rate. Hence, the effect is to change the multivalley semiconductor to a simpler single-valley semiconductor in which all of the electrons are confined to the [111] valley. Further, the nonlinear band gap change indicated for *pressure* greater than 15 kb would not be expected to occur, since detailed analysis[31] of the interband scattering of electrons showed that the effect was caused by the conduction band minima in the [100] direction moving closer in energy to the [111] minima thus causing significant interband scattering. In the one-dimensional strain configuration these two minima are further apart in energy in the strained state than in the unstrained state; thus no intervalley scattering would be expected.

On the other hand, the valence band structure becomes more complex in the one-dimensional strain state than in the hydrostatic state. One-dimensional [111] strain causes the $\Gamma'_{25(j=3/2)}$ edge to be split at a rapid rate. Further, the $\Gamma'_{25(j=1/2)}$ band, originally at the same energy as the $j = 3/2$ level, changes energy with a different coefficient than either of the split $j = 3/2$ levels. Thus, three distinct valence band energy levels exist at the same momentum value for which one level exists in the unstrained and the hydrostatic state.

The band gap for Ge in [111] one-dimensional strain is predicted to be narrowed from $0{\cdot}66$ eV to $0{\cdot}46$ eV at 2% strain. Because of this, deeper lying impurity levels unimportant in the unstrained or hydrostatic state are possibly more important in the uniaxial strain state. Hence, it is clear that because of these several major differences in band structure, results and conclusions concerning conductivity of hydrostatically strained Ge are of marginal applicability to the analysis of [111] one-dimensionally strained Ge.

Noting the simplicity of the one-dimensionally strained conduction band, it is interesting to use the position of the L_1 minimum as a reference and compute the effective energy level of the valence

* A bulk modulus of $7{\cdot}49 \times 10^2$ kb was used to calculate the volume dependence from the measured pressure dependence[30] of the energy gap.

† Wave transit time for this sample is $1{\cdot}42$ μsec.