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Intervalley scattering in n type Ge from a Hall effect experiment to high pressures

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Abstract. Hall effect measurements on n type Ge to 65 kbar are described. The Hall mobility of electrons through the transfer from ⟨111⟩ to ⟨100⟩ states has been measured and an assessment of the scattering parameters for the different intervalley and intravalley processes has been made following the analysis of Nathan and co-workers in 1961. Results are compared with the more complete theory of Fawcett and Paige, and reasonable agreement is found. The Hall mobility of electrons in the ⟨100⟩ valleys is determined as $1020 \pm 170\,cm^2\,V^{-1}\,s^{-1}$, the ⟨100⟩ effective mass is estimated to be ~ 50% greater than for n type Si and the ⟨100⟩–⟨111⟩ energy sub-band gap is $0{\cdot}186 \pm 0{\cdot}010$ eV. Nonequivalent intervalley scattering between the ⟨111⟩ and ⟨100⟩ valleys is shown to reduce the mobility by a factor of two near band cross-over. Results are directly relevant in determining coupling constants between valleys in high electric field calculations, involving ⟨100⟩ and ⟨111⟩ minima, as in InP.

1. Introduction

The low electric field properties of n type Ge at atmospheric pressure are now well understood. The electrons occupy four ellipsoidal minima at L_1 points at the ⟨111⟩ zone edge. At high pressures, however, an electron transfer to a higher lying set of minima takes place. The work of Bridgman and Paul (unpublished; results are reported in Nathan *et al.* 1961) and Nathan *et al.* (1961) was instrumental in showing that these minima were in the ⟨100⟩ direction at Δ_1 points in from the zone edge, similar to the occupied minima in n type Si at atmospheric pressure. Thus n type Ge can be converted by the application of high pressure into a semiconductor whose properties resemble those of Si. This effect allows us to make some interesting comparisons concerning the scattering properties and effective masses in the equivalent minima for the two semiconductors.

The high electric field properties of n type Ge are the subject of some discussion. The problem is discussed in an exhaustive Monte Carlo calculation by Fawcett and Paige (1971), who suggest that electron transfer to the higher density of states Δ_1 minima at high fields can explain all the reported data, including the negative differential mobility below 150 K observed by McGroddy and Nathan (1967). Pressure measurements are extremely useful in providing some idea of the parameters, such as sub-band energy gaps, effective masses, and deformation potentials, which can be used in these high field calculations to give a better understanding of high field transferred electron devices.

The pressure experiments reported to date have been confined to simple resistivity measurements below 30 kbar (Nathan *et al.* 1961) or p–n junction measurements (Jayaraman and Kosicki 1968). In neither case was the pressure high enough to eliminate scattering to the L_1 minima. Further recent high field, high pressure measurements are adequately discussed by Fawcett and Paige (1971). This paper describes Hall measurements to pressure (65 kbar) which are high enough to isolate electrons in the Δ_1 minima, well past L_1–Δ_1 band cross-over. Also for the first time, the mobility of electrons during band cross-over and in the ⟨100⟩ valleys has been measured. This has allowed us to observe directly how