

Characterization of process and radiation induced defects in Si and Ge using conventional deep level transient spectroscopy (DLTS) and Laplace-DLTS

By

Cloud Nyamhere



Submitted in partial fulfillment of the requirements for the degree of

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Supervisor/Promoter: Prof. F.D. Auret

Co-supervisor: Dr W.E. Meyer

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Defects in semiconductors are crucial to device operation, as they can either be beneficial or detrimental to the device operation depending on the application. For efficient devices it is important to characterize the defects in semiconductors so that those defects that are bad are eliminated and those that are useful can be controllably introduced.

In this thesis, deep level transient spectroscopy (DLTS) and high-resolution Laplace-DLTS (LDLTS) have been used to characterize deep level defects introduced by energetic particles (electrons or Ar ions) and during metallization using electron beam deposition on silicon and germanium. Schottky diodes were used to form the space-charge region required in DLTS and LDLTS measurements. From the DLTS and LDLTS measurements the activation enthalpy required to ionize a trap, E_T , and defect carrier capture cross-section σ were deduced. LDLTS proved particularly useful since it could separate deep levels with closely spaced energy levels (the limit being defects with emission rates separated by a factor greater than 2), which was not possible by conventional DLTS.

The majority carrier traps in gallium-, boron- and phosphorus-doped silicon introduced after MeV electron irradiation and during electron beam deposition have been characterized, and several defects such as the divacancy, *A*-center and *E*-center and other complex defects were observed after the two processes. Annealing studies

have shown that all deep levels are removed in silicon after annealing between 500°C - 600°C.

Both electron and hole traps introduced in n-type germanium by electron irradiation, Ar sputtering and after electron beam deposition have been characterized using DLTS and LDLTS. The *E*-center is the most common defect introduced in germanium after MeV electron irradiation and during electron beam deposition. Annealing shows that defects in germanium were removed by low thermal budget of between 350°C - 400°C and it has been deduced that the *E*-center (V-Sb) in germanium anneals by diffusion.

The identification of some of the defects was achieved by using defect properties such as defect signature, introduction rates, annealing behavior and annealing mechanisms, and then comparing these properties to theoretical defect models and results from other techniques.

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