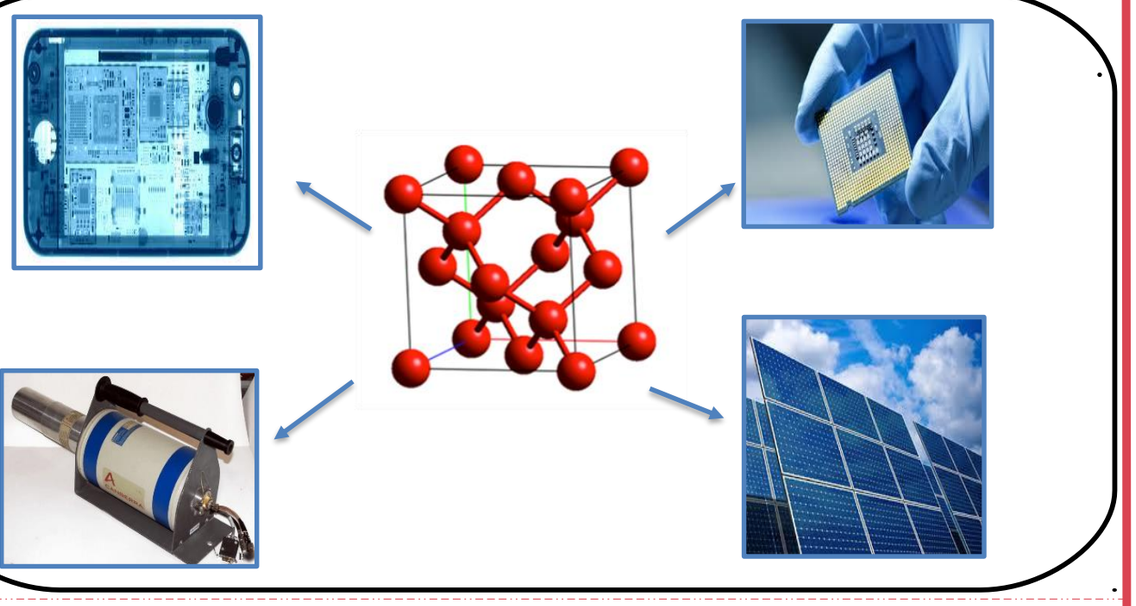
High resolution Laplace deep level transient spectroscopy characterization of radiation induced defects in germanium.

C.R. Thaba, F. Taghizadeh, F. D. Auret and M.M. Diale,
Department of Physics, University of Pretoria,0002, South Africa

Introduction

Germanium has drawn attention as a replacement of silicon as an ultrafast complimentary metal-oxide semiconductor device since it has higher carrier mobility which led to a better device performance [1]. There have been several studies on irradiation defects in germanium for the past decade and electronic properties such as energy level, apparent capture cross-section were investigated.[2].Defects have a significant influence on the electrical properties of semiconductor. They can be introduced by different methods, e.g. during crystal growth, ion implantation, annealing etc.[3]. In this work, DLTS and L-DLTS were used to study the alpha radiated defect in Ge.

Structure and application:



Experimental methods

The process used in this study for the purpose of preparing each sample is as follows:

- 3 steps degrease using trichloroethylene, isopropanol and methanol.
- Samples were placed in an ultrasonic bath for 5minutes for each degreasing step.
- The samples were rinsed with deionized water.
- Etched in a solution containing a mixture of hydrogen peroxide (H_2O_2) and deionized water in a (1:5) volume ratio for 1 minutes.
- The sample were rinsed again with deionized water and blown dry with nitrogen gas.
- Deposition of Au ohmic contact on surface of the substrate (Ge) using resistive evaporation system. .
- Thermal annealing of the ohmic contact in an Ar filled environment at 350 °C for 10 minutes.
- The same cleaning and etching of the samples used before, was used for fabrication of Schottky barrier diodes (SBD).
- Pd contacts were fabricated using the resistive evaporation technique at a deposition rate of ~0.1 nm s^{-1} with thickness of 100nm.
- The sample were then irradiated for 60 minutes using an ^{241}Am source at room temperature.
- *I-V* and *C-V* measurements were used to check the quality of the contacts.
- The samples were characterised before and after alpha-particle irradiation by both convectional DLTS and high-resolution Laplace DLTS.

Results and Discussion

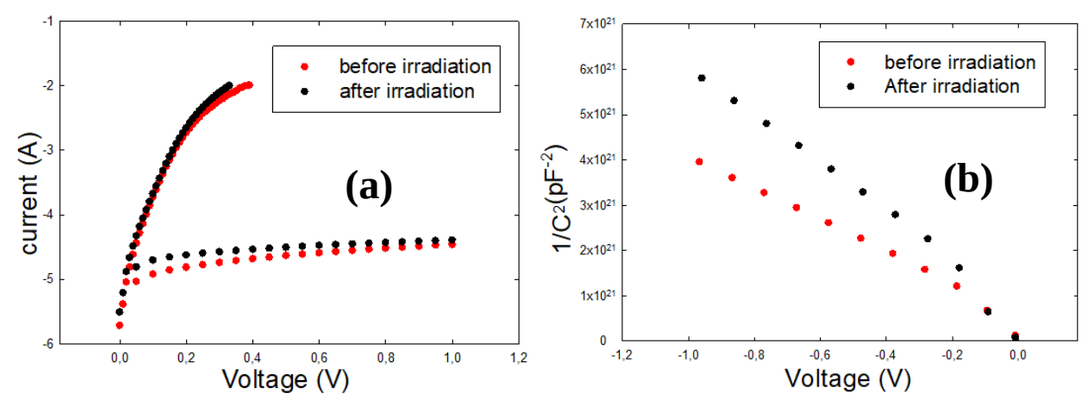


Fig.1: (a) I-V plot and (b) C-V plots of Pd/n-type germanium SBDs before and after alpha -particle irradiation.

Linearity of *the I-V* plot for the unirradiated samples displays the high quality of n-Ge devices as its ideality factor is n = 1.317 but after irradiation, the ideality factor increased to n = 1.373.
Carrier density decreased by irradiation from (1.58× 10^{15} ⟹ 1.04× 10^{15}) cm^{-3}

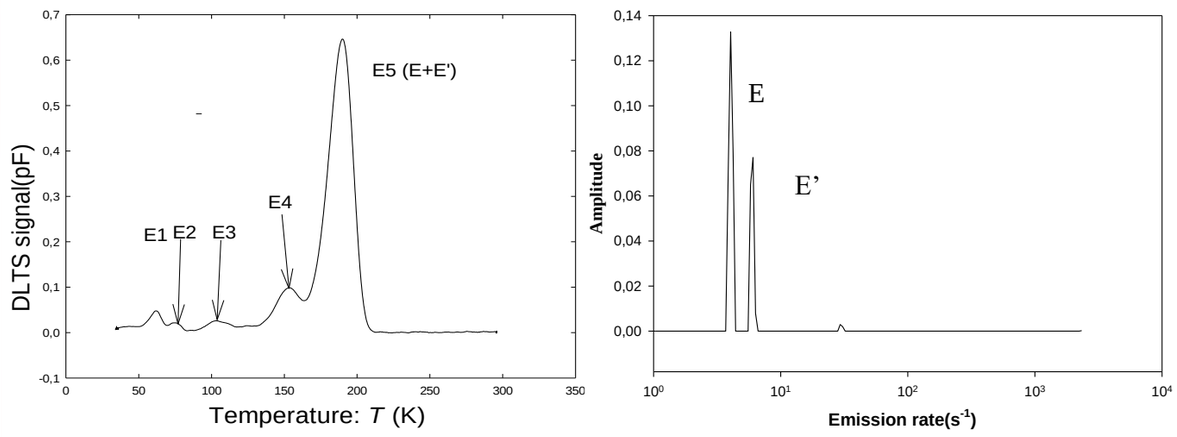


Fig.2 DLTS and Laplace spectra of Ge sample.

The conventional DLTS spectrum illustrates the presence of 5 peaks and peak E and E' were separated using manual regularization parameters.

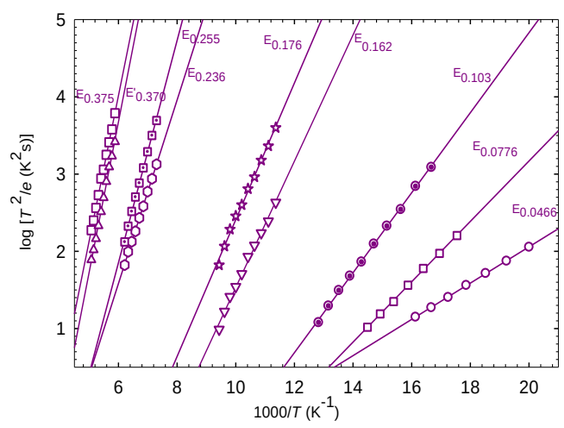


Fig.3 display the Arrhenius plots of n-type Ge sample by high energy alpha particles irradiation from an 241Am source.

From the slope and intersection of the Arrhenius plot, the activation energy and apparent capture cross-section can be obtained.
For E and E it was found the Et = 0.370 eV and 0.375 eV, respectively

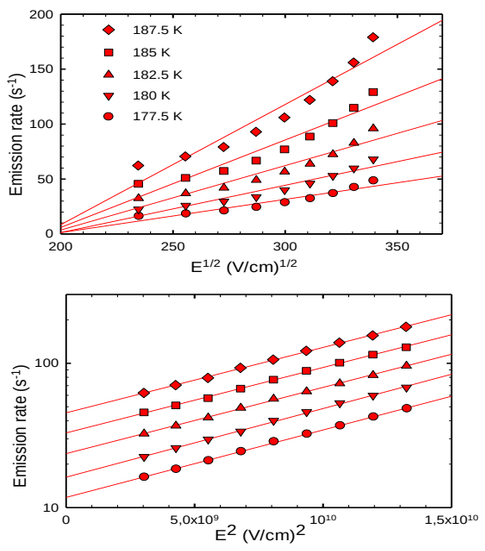


Fig.4: The electric field dependence plot for the E defect.

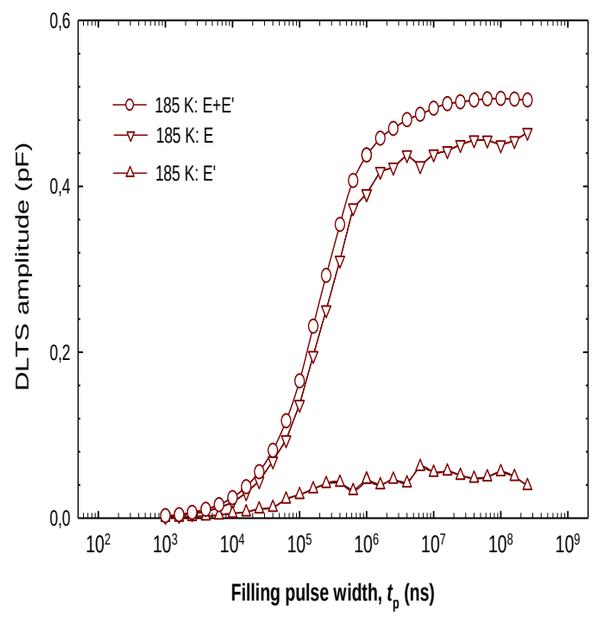


Fig.5:The plot relating the amplitude of a Laplace DLTS peak to the pulse width.

Conclusion

- Pd Schottky contacts were fabricated by resistive deposition technique.
- The *I-V* and *C-V* measurements were used to determine the suitability of the devices by determining the ideality factor and carrier concentration which were found to be to n = 1.317 and 1.58×10^{15} cm^{-3}, respectively before irradiation and n = 1.373 and 1.04×10^{15} cm^{-3},respectively after irradiation.
- High resolution Laplace Deep-Level Transient Spectroscopy (L-DLTS) was used to study the electrical properties of E and E' defects in germanium (Ge) which were introduced by alpha particle radiation.
- The activation energies for E and E' were found the E_t = 0.370 eV and 0.375 eV, respectively.
- Electric field dependence of E defect was measured in different temperature to distinguish between Poole-Frenkel and phonon-assisted tunnelling and is described by phonon-assisted tunnelling
- Both components are structurally different.

References

1. J. Bean and R. Hull, "Germanium Silicon: Physics and Materials, Volume 56 - 1st Edition.

2. P. Clauws and E. Simoen, "Metals in germanium," Mater. Sci. Semicond. Process., vol. 9, no. 4-5 SPEC. ISS., pp. 546–553, Aug. 2006.

3. W. E. Meyer, "Digital DLTS studies on radiation induced defects in Si, GaAs and GaN" by Walter Ernst Meyer PhD (Physics) in the Faculty of Natural & Agricultural Science University of Pretoria November 2006.