Alpha-particle induced defects on single-crystal ZnO

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Introduction

- ZnO has an experimental direct bandgap of 3.4 eV, which plays a role in realizing blue and ultraviolet light emitting devices, such as lasers, light emitting diodes and daylight-blind UV detectors, as is the case for GaN with a similar bandgap [1, 2].
- Further advantages of ZnO include bulk-growth capability, amenability to conventional wet chemistry etching & is compatible to Si technology.
- For space applications, these devices have to operate at elevated temperatures, approximately above 200°C, in harsh conditions comprising of energetic particles [3].
- This study report on the electrical characterization of high-energy alpha-particles bombarded single crystal ZnO.

Experimental

- Undoped ZnO samples from Cermet Inc, were degreases in acetone and methanol for five minutes in an ultrasonic bath and etched in hydrogen peroxide and blown dry with nitrogen gas.
- Pd Schottky contacts with thickness 60 nm and ohmic contact with a composition of Al/Au with relative thickness of 50/30 nm were deposited using resistive evaporation.
- The Schottky barrier diodes were bombarded at room temperature with 1.6 MeV alpha-particles in the Van de Graaff accelerator.
- The defects introduced during the irradiation were characterized by conventional DLTS.

Results and discussion

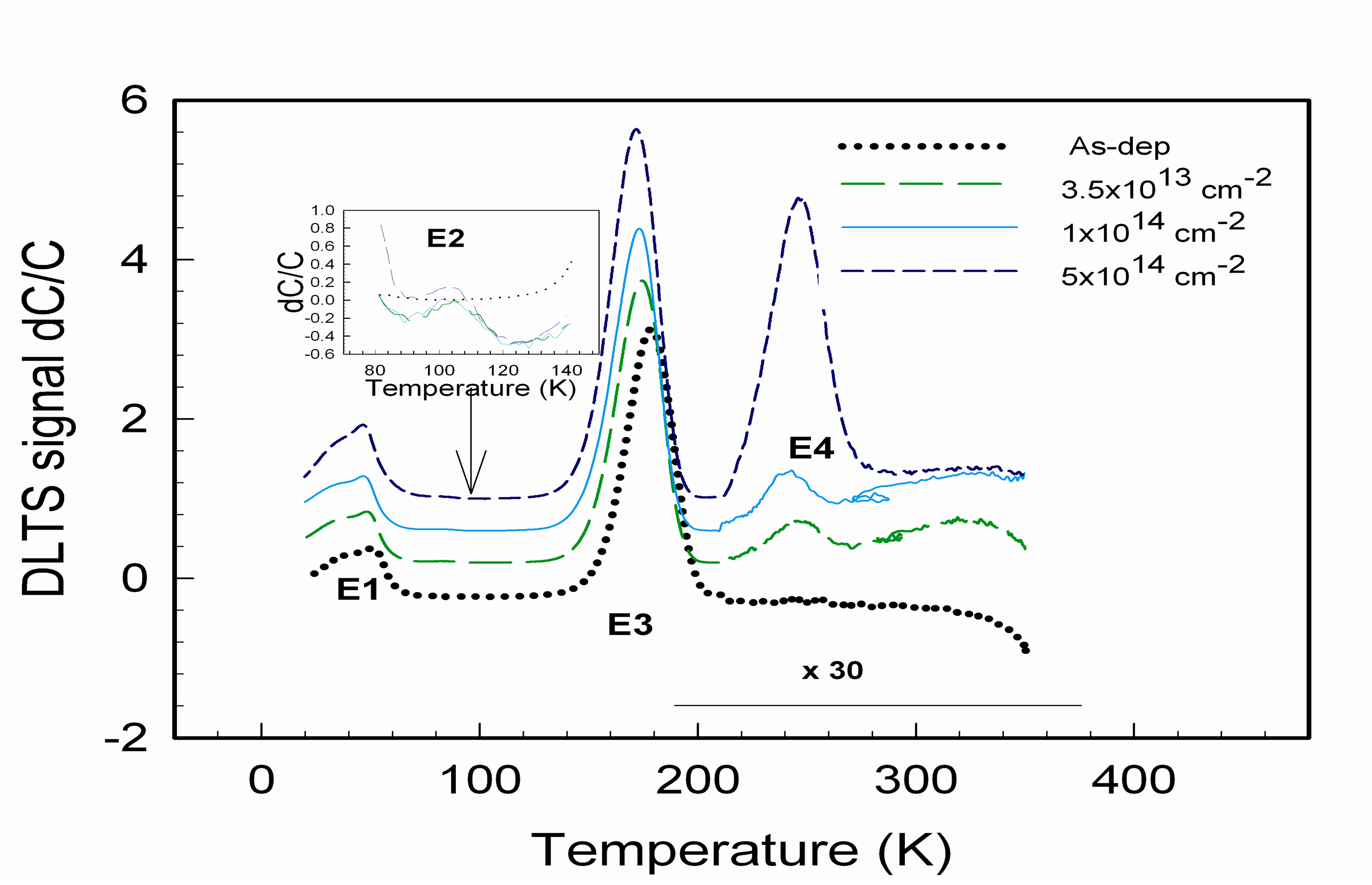

Figure 1: DLTS spectra of as deposited and 1.6 MeV Pd/ZnO Schottky barrier diodes. All spectra were recorded using a quiescent reverse bias 2V, a filling pulse amplitude of 2.2V and filling pulse width of 0.2 ms. The insert shows the E2.

- In figure 1 defects (E1 & E3) are common defects in ZnO regardless of the growth, processing and contact fabrication techniques.
- Defects (E2 & E4) are introduced after the samples were bombarded with alpha-particles.
- E2 has not been observed in some other ZnO materials [4].
- However, the E4 has been observed to be induced by annealing and high-energetic particle irradiations [5].
- The Arrhenius plots in figure 2 presents the estimate activation enthalpy and apparent capture cross-section of the E1, E2, E3 and E4 deep level defects.
- Activation enthalpy of defect E1~72, E~86, E3~304 and E4~518 meV.
- In figure 3 the freeze out region of ZnO starts occurring at a temperature of about 50K.
- The position of the E1 peak near the freeze out region can influence the accurate determination of its activation enthalpy and capture cross-section.

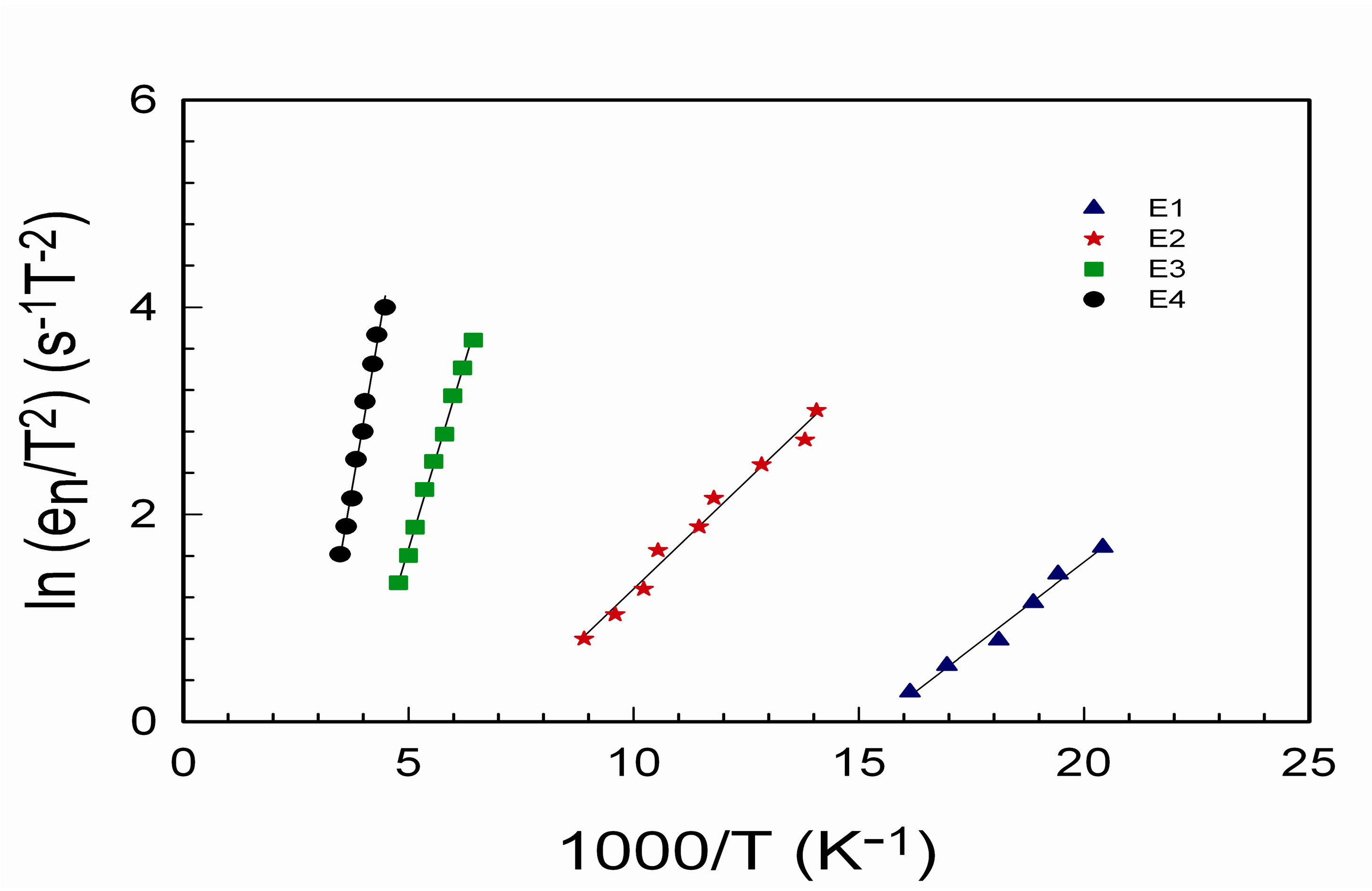

Figure 2: Arrhenius plot obtained from the 1.6 MeV alpha-particle irradiated Schottky barrier diodes.

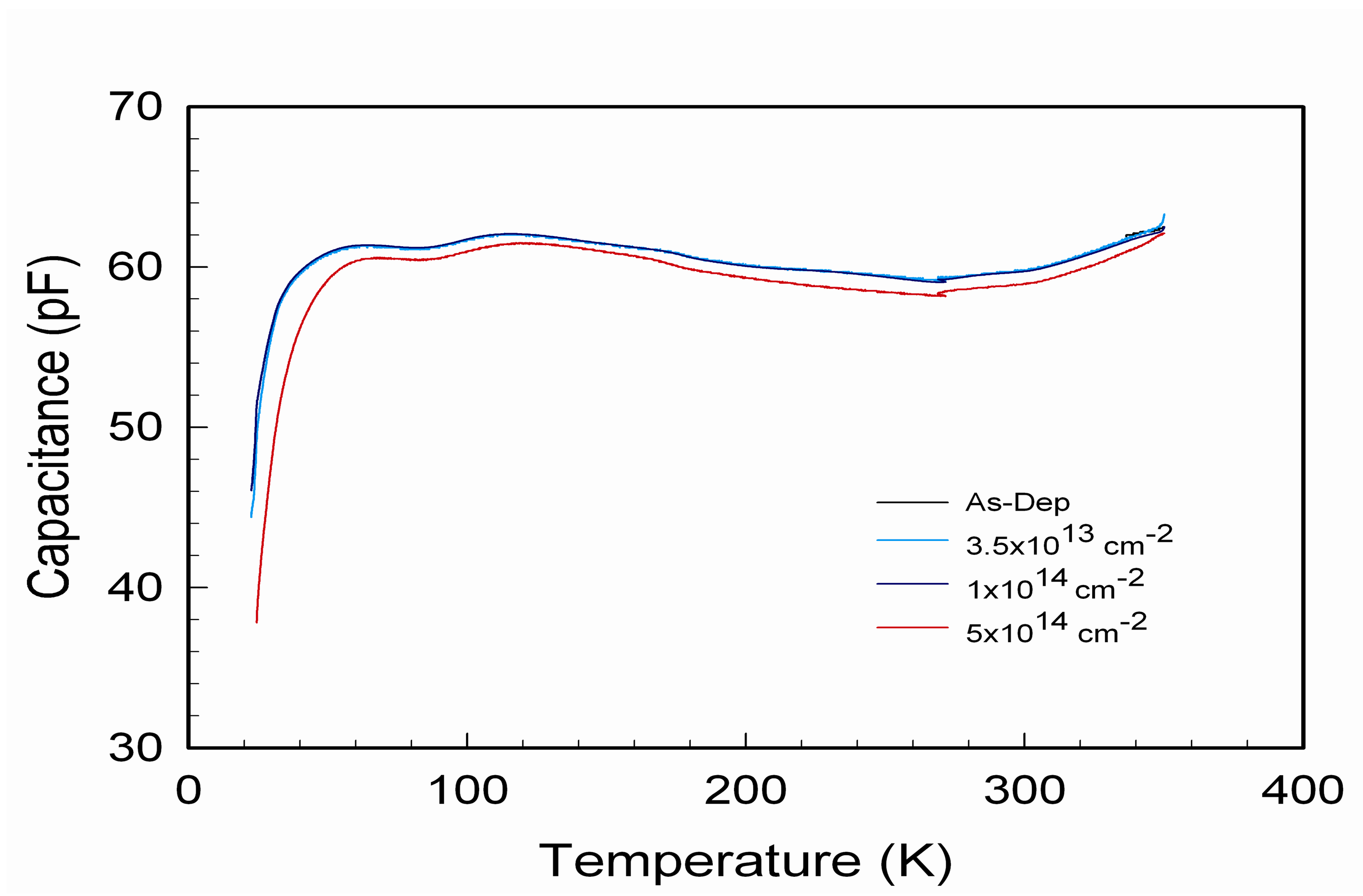

Figure 3: Capacitance-temperature scan obtained as grown and 1.6 MeV alpha-bombarded Pd/ZnO Schottky barrier diodes. The spectra were recorded at quiescent reverse bias of 0V in the 20-350 K temperature range.

Conclusion

- Exposing ZnO to alpha-particles introduces a new deep level defect
- The defect concentrations indicate that ZnO is extremely resistant to room temperature MeV irradiation when compared to other semiconductors, including GaN.
- The irradiation induced peak has proven to be stable for the dosage of particles bombarded in this particular study.
- ZnO can be used for space application for much longer periods of time than any other semiconductor with similar electro-optical properties.

Reference

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