Hydrogen passivation of nitrogen related energy levels in ZnSe and ZnSSe grown by MBE

D. Seghier[1], J. T. Gudmundsson,

and H. P. Gislason

Science Institute,

University of Iceland,

Dunhaga 3,

IS-107 Reykjavík,

Iceland,

[1]seghier@hi.is

In previous work we reported the observation of three hole traps in N-doped ZnSe and ZnS_xSe_{1-x} films grown by MBE [1] :

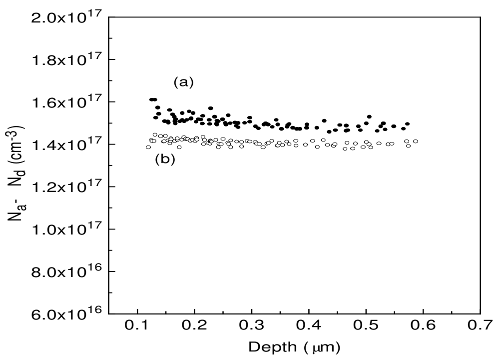
- T1 at $E_v + 0.11$ eV, attributed to a dominating nitrogen acceptor
- T2 at $E_v + 0.46$ eV, attributed to the nitrogen doping
- T3 at $E_v + 0.56$ eV, attributed to the nitrogen doping

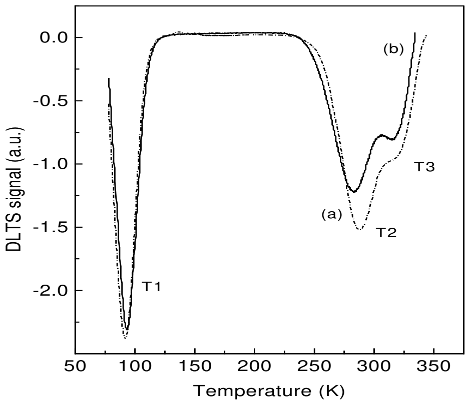
In the present study we investigated the effect of hydrogenation on these hole traps.

- We found that samples with $N_a - N_d$ less than a few times 10^{16} cm^{-3} become highly resistive after the hydrogenation.
- In samples which remained conductive the hydrogenation caused a decrease in the DLTS peak heights of T2 and T3 within 0.4– 0.5 µm from the surface.
- In samples with $N_a - N_d$ around $2 - 5 \times 10^{16}$ cm^{-3} we observe a similar decrease in the DLTS peak height of level T1 and the net charge density which shows its role in the hole conductivity of the samples.
- Hydrogenation of samples with $N_a - N_d$ in the 10^{17} cm^{-3} range did not affect the net charge density or height of T1 much.

Sample	Material	$(N_A - N_D)$ [cm^{-3}]
1	ZnSe	8×10^{15}
2	ZnSe	3×10^{16}
2a	ZnSSe	5×10^{16}
3	ZnSe	1.5×10^{17}
3a	ZnSSe	4×10^{17}

List of samples used in the investigation. The charge concentrations refer to as-grown samples.

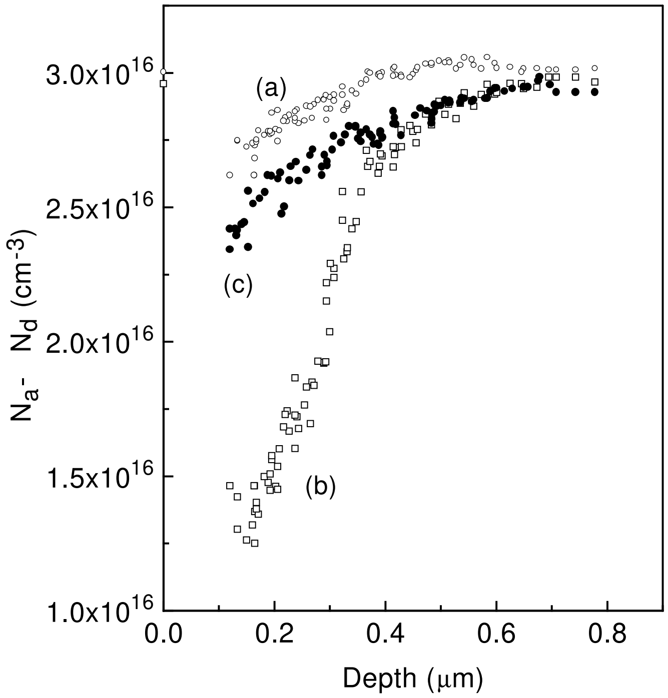




For $N_a - N_d \approx 1.5 \times 10^{17}$ cm^{-3} the hydrogenation has little effect on the active acceptor concentration.

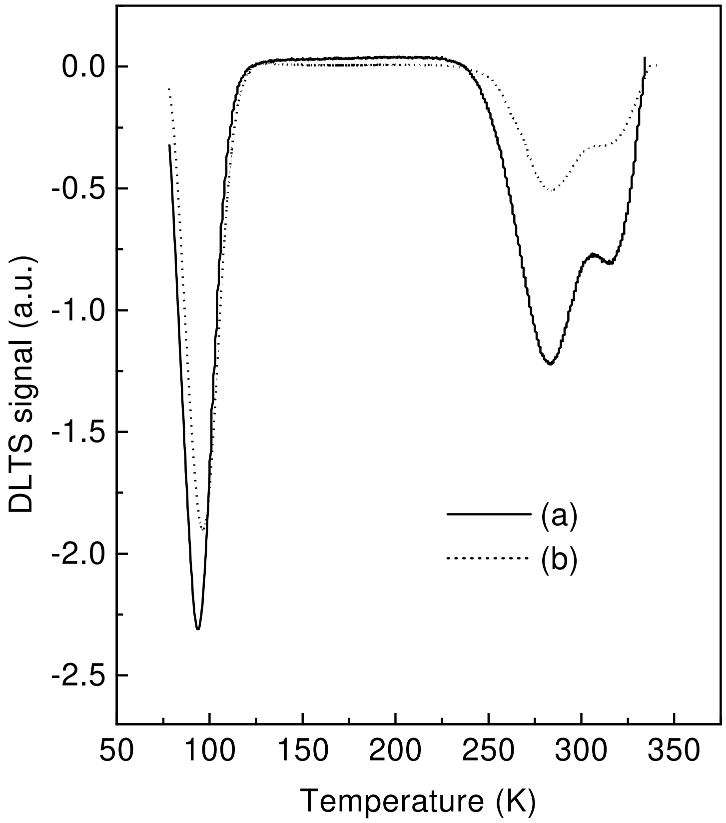
The net charge concentration $N_a - N_d$ for sample 2

- (a) as grown
- (b) after hydrogenation in H_2/Ar plasma in a planar inductive discharge
- (c) after annealing at 200 °C under reverse bias $V_r = 1$ V for 10 min



The DLTS spectra for sample 2

- (a) as grown
- (b) after hydrogenation



Traps T2 and T3 were attributed to the nitrogen doping [1, 2] and found to have low concentration in all samples, the highest one 10^{14} cm^{-3} in the samples with highest net acceptor density.

- In all the conductive samples a decrease in the peak heights of the DLTS signal from traps T2 and T3 was observed.

- We observe less reduction in samples with higher net acceptor density, confirming that the concentration of these traps increases with $N_a - N_d$ since all the hydrogenated samples were subject to the same hydrogen exposure.

- The fact that incorporation of hydrogen which completely passivates about 10^{16} cm^{-3} of T1 traps only partially passivates less than 10^{14} cm^{-3} T2 and T3 traps requires further investigation.

In conclusion we studied the net acceptor concentration $N_a - N_d$ in nitrogen-doped $p-$type ZnSe and ZnS_xSe_{1-x} with $x = 0.08$ before and after exposure to H_2/Ar plasma:

- A direct passivation of the 0.11 eV acceptor level occurs after hydrogenation
- There is a corresponding reduction of net acceptor density in the samples.
- The results support the attribution of this dominating acceptor level to nitrogen.

This research was supported by the Icelandic Research Council and the University Research Fund. We are grateful to Prof. B.C. Cavenett and Prof. K.A. Prior for providing the samples used in this study. J.T.G. thanks the hospitality of Prof. M. A. Lieberman and the experimental assistance of A. M. Marakhtanov at University of California at Berkeley where the hydrogenation was performed.

References

[1] D. Seghier and H. Gislason, Applied Physics Letters **71** , 3026 (1998).

[2] I. S. Hauksson, J. Simpson, S. Y. Wang, K. A. Prior, and B. C. Cavenett, Applied Physics Letters **61**, 2208 (1992).