CONF-950820--1

Eleventh International Conference on the
Electronic Properties of Two-Dimensional Systems

HIGHLY DOPED p-ZnTe FILMS AND QUANTUM WELL STRUCTURES GROWN BY NONEQUILIBRIUM PULSED LASER ABLATION

Douglas H. Lowndes,* C. M. Rouleau,* J. D. Budai,* D. B. Geohegan,* and J. W. McCamy†
*Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6056 USA
†Division of Applied Science, Harvard University, Cambridge, MA 02138 USA

Highly p-doped ZnTe films have been grown on semi-insulating GaAs (001) and unintentionally doped (p-type) GaSb (001) substrates by pulsed KrF (248 nm) excimer laser ablation of a ZnTe target through an N_2 ambient, *without the use of any assisting (DC or AC) plasma source.* Free hole concentrations in the mid-10^{19} cm^{-3} to > 10^{20} cm^{-3} range have been obtained. This appears to be the first time that any wide band gap ($E_g \geq 2$ eV) II-VI compound (or other) semiconductor has been impurity-doped from the gas phase by pulsed-laser ablation (PLA). The maximum carrier concentrations also may be the highest obtained for ZnTe by any method thus far.

PLA differs from other nonequilibrium growth methods in that p-type doping of ZnTe is believed to make use of the collisions between energetic ablated species and ambient N_2 molecules. Highly doped p-ZnTe has been grown recently by another nonequilibrium method, in which atomic nitrogen beams extracted from RF and DC plasma sources were used to produce p-type doping during molecular beam epitaxial deposition.[1,2] Subsequent infrared spectroscopic measurements showed that the specie responsible for p-doping in the RF experiments almost certainly was atomic nitrogen.[3] In contrast, our own spectroscopic measurements during laser ablation of ZnTe in molecular N_2 *do not reveal the presence of atomic nitrogen.* This suggests that the high hole concentrations in our ZnTe specimens are produced by a new and different mechanism, possibly transient formation of Zn-N compounds in the ablation plume, resulting in substitutional N incorporation in our ZnTe films.

The hole mobility in our p-ZnTe films reaches a maximum value at intermediate N_2 pressures (~100 mTorr), falling off at both higher and lower pressures. We tentatively attribute this behavior to the combined effects of ablation-beam kinetic energy (at low pressures) and possibly excessive nitrogen incorporation (at high pressures). This model is being examined with the help of in situ time-resolved intensified-CCD camera images of the ablation plume's propagation through nitrogen, and by spectroscopic and ion probe measurements of the energetic ablation plasma. SIMS, Hall effect, and RBS measurements of the epitaxial films also are used to assess dopant incorporation, dopant activation, and film stoichiometry, respectively.

Because pulsed laser deposition is inherently digital, attractive deposition rates can be combined with precise control of layer thickness in epitaxial multilayered structures. Typical deposition conditions are < 0.5 Å per laser pulse, with crystalline quality governed by tradeoffs between substrate temperature, pulse repetition rate, and the focused pulsed laser energy density . PLA's capability for growth of very thin epitaxial layers is being exploited and studied through growth of doped heteroepitaxial quantum well structures in the nearly lattice-matched ZnTe / CdSe // GaSb(substrate) system. Results obtained from growth and characterization of heterostructures in this system will be presented.

We emphasize that these results were obtained using a conventional pulsed laser deposition system lacking UHV capability. In combination with our recent discovery that epitaxial $ZnSe_{1-x}S_x$ films and heterostructures can be grown with continuously variable composition, by ablation of a single fixed-composition target through a variable-pressure ambient gas,[4] this work appears to open the way to explore PLA growth and doping of compound semiconductors as a possible alternative to molecular beam epitaxy.

This work was supported by the Division of Materials Sciences, U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

[1] T. Baron et al., *Appl. Phys. Lett.* **65**, 1284 (1994)
[2] S. O. Ferreira et al., *J. Cryst. Growth* **140**, 282 (1994).
[3] R. P. Vaudo et al., *J. Cryst. Growth* **138**, 430 (1994).
[4] J. W. McCamy and D. H. Lowndes, *Appl. Phys. Lett.* **63**, 3008 (1993).

Oral Presentation Strongly Preferred

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Corresponding Author:

Dr. Douglas H. Lowndes
Solid State Division
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6056 USA

Phone: (615) 574-6306
FAX: (615) 574-4814
E-mail: vdh@ornl.gov (Internet)

Principal Co-Author:

Dr. C. M. Rouleau
Solid State Division
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6056 USA

Phone: (615) 574-6284
FAX: (615) 574-4814
E-mail: xuc@ornl.gov (Internet)