High quality monocrystalline ZnO films grown at low temperature by Atomic Layer Deposition

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Atomic Layer Deposition

We used the ALD (Atomic Layer Deposition) technique to grow monocrystalline ZnO. The characteristic features of this method are:

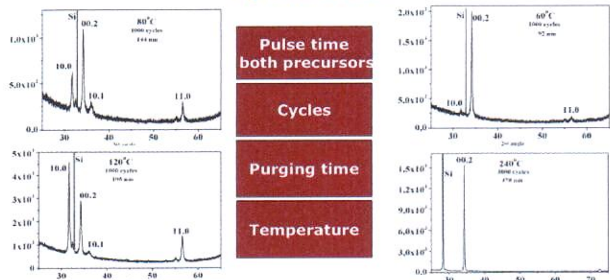
✓ possibility of use very reactive precursors like diethylzinc or dimethylzinc
✓ sequential procedure based on the reaction of synthesis, single exchange and double exchange;
✓ self limiting process.

Example of double exchange chemical reaction:

$$C_2H_5 - Zn - C_2H_5 + H_2O \rightarrow ZnO + 2C_2H_6$$

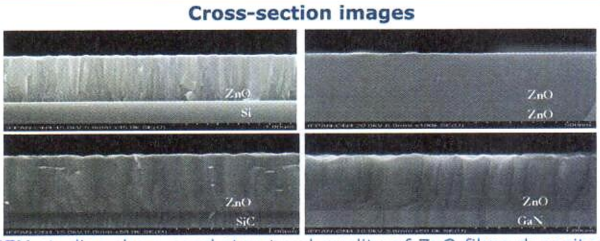
Savannah 100 DEZn and deionized water precursors

Optimization



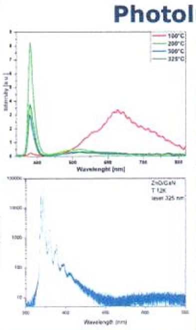
In our experiment we varied pulse time of both (water and diethylzinc) precursors, purging time, number of cycles and temperature. We observed changes in crystallographic orientation.

Cross-section images



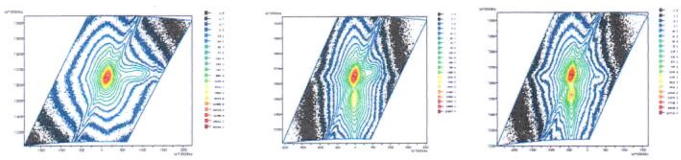
SEM studies show good structural quality of ZnO films deposited on different substrates. Best monocrystalline quality was obtained for zinc oxide and gallium nitride substrates.

Photoluminescence characterization



PL studies show that strong excitonic emission is observed even at room temperature for different growth temperature. The main features of PL spectra: FWHM of band-edge PL is equal to 4.4meV , the high of energy peak is located at 3.33 eV and corresponds to a deep acceptor or free-to-bound transition. The LTPL peak located at 3.36 eV might be related to neutral donor bound exciton recombination. The logarithmic scale enables observing a bound exciton, a free exciton and phonon repetitions, which is a fingerprint of a high optical quality of obtained samples.

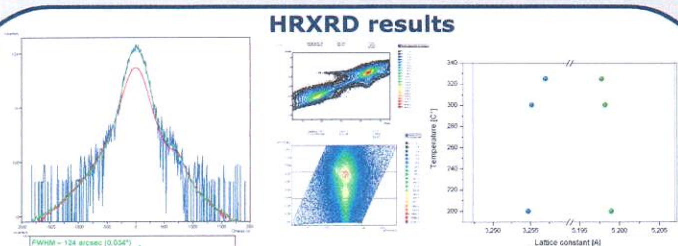
Temperature dependence

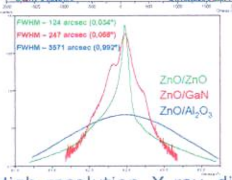


100°C 200°C 300°C

We obtained monocrystalline zinc oxide on gallium nitride substrates at **200°C** temperature. Images show symmetrical 00.6 reflection.

HRXRD results



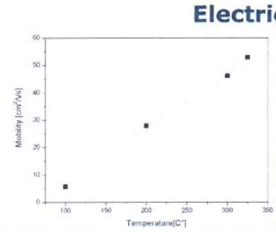


Substrates	Latice a [Å]	Latice c [Å]
ZnO	3,2507	5,2067
GaN	3,2569	5,1978
Al_2O_3	3,2488	5,2057

Bulk crystal:
a = 3.2495 Å
c = 5.2069 Å

High-resolution X-ray diffraction spectra shows that ZnO films are monocrystalline, with a FWHM of their associated rocking curves of approximately 247 arcsec for heteroepitaxial growth and 124 arcsec for homoepitaxial growth.

Electrical parameters



Temperature	n [cm-3]	μ [cm2/Vs]
100	$4{,}66 \cdot 10^{18}$	5,74
200	$2{,}31 \cdot 10^{19}$	27,85
300	$4{,}16 \cdot 10^{18}$	46,05
325	$2{,}94 \cdot 10^{18}$	52,70

Hall measurements showed n-type behavior with a carrier mobility of 52,7 cm^2/Vs for glass substrate and 189 cm^2/Vs for gallium nitride substrate

Conclusion

We show how ZnO growth depends on process parameters and illustrate difference in quality of zinc oxide layers grown on various substrates like a gallium nitride, zinc oxide, silicon and silicon carbide. High Resolution X-ray diffraction spectra showed that FWHM of the symmetrical 00.2 reflection equals to 0.07° for monocrystalline growth on GaN substrates. In low temperature photoluminescence we observed a sharp excitonic line in band-edge region with FWHM of 4 meV. The defect-related luminescence was not present in our samples.

Acknowledgements

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