Epitaxial Deposition of ZnO

Abstract

Thin films of ZnO were deposited by MOMBE on r-plane Al_2O_3 and homoepitaxially on ZnO (0001) single crystal surfaces. On Al_2O_3 the glideplane symmetry is transferred to the film and for homoepitaxial films a stepped 0001 surface is observed by LEED.

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Introduction

Deposition of ZnO films of high crystalline quality has gained interest due to the possible applications in the field of laserdiodes, displays and solar cells. The understanding of the surface and interface properties of ZnO is still poor as far as the electronic structure is concerned. The bulk electronic structure was investigated in the past but discrepancies to theoretical calculations still exists. Here we report on the preparation and characterisation of thin ZnO films under controlled UHV conditions.

Experimental

ZnO films were deposited in an UHV-MOMBE system from the precursors diethyzinc and water at growth pressures in the 10^{-5} mbar range. Deposition temperature was 450 °C. Annealed r-plane Al_2O_3 crystals and a (0001) surface of a ZnO single crystal were used as substrates. The single crystal was prepared by sequential Ar^+ sputter anneal cycles. Samples were characterised in situ by photo electronspectroscopy (UPS, XPS) and electron diffraction (LEED) without breaking UHV conditions.

Results

On the r-plane of Al_2O_3 ZnO grows epitaxially with the (11-20) plane in registry with the substrate. The XPS data show clean ZnO with no residuals of carbon proving a clean reaction at the interface. In the O1s spectra an admixture of about 5-10 % hydroxide is found which can be removed by annealing to 600 °C. UPS data show no differences between a (11-20) single crystal and the film grown on saphire. As the differences are only obvious for the as deposited film in the HeII spectra with the inherential increased surface sensitivity, we conclude that we observe the signature of a surface terminated with hydroxide.

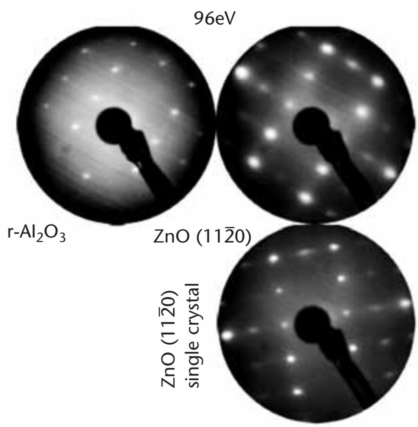

Figure 1
LEED pattern of the Al_2O_3 substrate, epitaxial film and the corresponding single crystal surface at 96eV electron energy. The epitaxial relation is for the film and the substrate nicely demonstrated.

The LEED *(Fig. 1)* analysis shows that the glide plane symmetry of the substrate is transferred to the growing film, preventing a growth in different domains. Slightly broader spots in comparison to a single crystal surface are due to the lattice mismatch between substrate and film. AFM data obtained ex situ show a film surface roughnes of 2 nm which reduces to 1.5 nm after annealing the sample. Carrier concentration is found to be below 10^{-19} cm^{-3} with mobilities above 13 cm^2/Vs. The quality of the films was sufficient to obtain angular resolved photoemission data (ARUPS) from the surfaces *(Fig. 2)*.

Admixture of thermally excited hydrogen during growth revealed in the O1s Photoemission spectra the well known hydroxide signature which is removed by annealing the sample. The electrical behaviour of the hydrogen exposed film is somewhat confusing. As for H incorporation in ZnO n-type doping is expected, the films revealed a very low conductivity showing up as a photocurrent induced rigid shift of the spectra. SEM shows an increase of roughness for H-assisted growth, which is reduced after annealing the samples.

Homoepitaxial films were deposited on ZnO (0001) single crystal surfaces. Again LEED pattern of high quality are observed. As the surface of the subtrate was rather rough Step formation is observed in the LEED data. XPS and UPS data show no contamination from residual hydrocarbons. As the quality of the supplied crystals is restricted by the hydrothermal growth methode (Li, Na, K, Ca contaminations) we try to grow homoepitaxial overlayers for a more detailed study of the surface properties of ZnO.

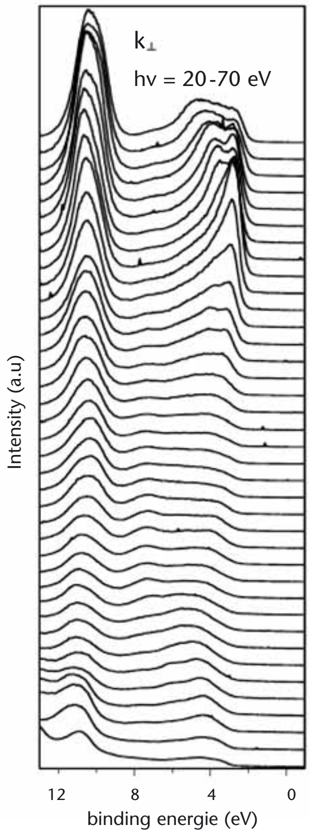

Figure 2
ARUPS data for a ZnO (11-20) film deposited on saphire recorded in normal emission showing clearly the dispersion of the valence bands.