

## 2.5 Polarization-dependent beam switch based on a strained *M*-plane GaN/AlN distributed Bragg reflector grown on LiAlO<sub>2</sub>

Group-III nitrides of the wurtzite crystal structure exhibit linear birefringence, i.e. the refractive index is different for the light polarized parallel and perpendicular to the *c* axis. This effect can be utilized in films grown on non-polar surfaces, where the *c* axis lies in the film plane. A distributed Bragg reflector (DBR) with this orientation will exhibit two distinct stop bands depending on the linear polarization state of the incident light. For light with an incidence angle of 45°, the DBR can be used as a beam switch at wavelengths where the reflectance of one polarization and the transmittance of the other polarization are large. In this wavelength range, a linearly polarized beam is either transmitted or reflected depending on the polarization. An arbitrarily polarized light beam will therefore be split into two components, one parallel and the other perpendicularly polarized to the *c* axis. One component is transmitted, while the other is reflected.

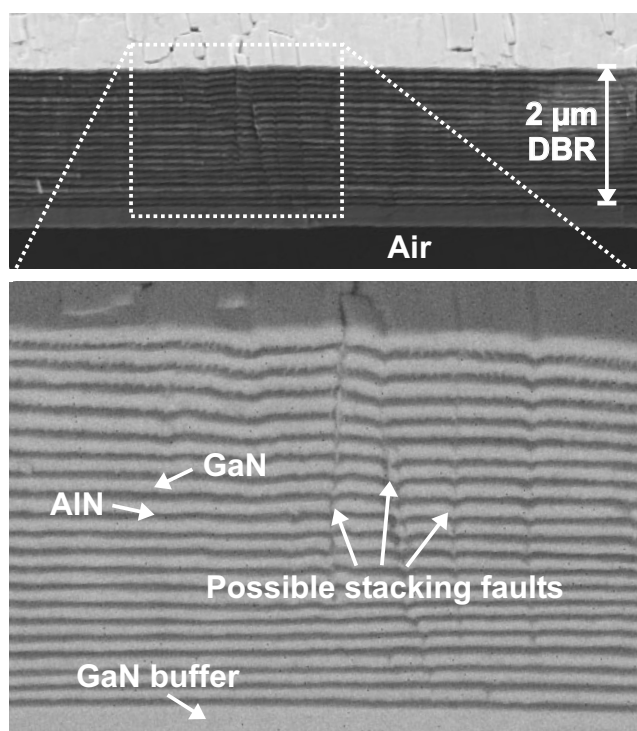


Fig. 13. SEM image of a free-standing AlN/GaN distributed Bragg reflector grown on a GaN buffer layer after peeling off from the LiAlO<sub>2</sub> substrate.

The samples were grown on epi-ready  $\gamma$ -LiAlO<sub>2</sub>(100) substrates by plasma-assisted molecular-beam epitaxy. Growth was initiated by depositing a 300-nm-thick GaN buffer layer. To achieve a high reflectivity at a design wavelength of 433 nm (assuming an isotropic dielectric function for GaN and AlN), 20 periods of 43.8 nm AlN/51.6 nm GaN layers were grown under metal rich conditions. Due to temperature inhomogeneities in the sample holder, some areas contained excess metal on the surface, which leads to crack formation and film peeling. Figure 13 shows a scanning-electron-microscopy (SEM) image of such a free standing DBR fragment. The buffer layer as well as the DBR structure

are clearly visible in the magnified image shown in the bottom part of the figure. Possible stacking faults are also visible. The interfaces between the AlN and the GaN layers are disturbed at these faults.

To test the concept of a polarization-dependent beam switch, the DBR samples were placed at an angle of 45° with respect to an incident beam. The light was polarized either parallel or perpendicular to the *c* axis. For both polarizations, transmittance and reflectance curves were

measured simultaneously as shown in Fig. 14(a). Two distinct stop bands are clearly visible, centered at 425 nm for perpendicular and at 435 nm for parallel polarization, respectively. The reflectance only reaches values of about 80% due to interface roughness, metal droplets, and cracks in the film. Light scattering due to roughness at the backside of the substrate leads to a strong reduction in the transmittance. Improvements in substrate polishing and optimized growth conditions should yield higher values.

Switching of a light beam, which is linearly polarized parallel or perpendicular to the  $c$  axis, is accomplished when the reflectance of one polarization and the transmittance of the other polarization are large. A switch gain can be defined as the product of these quantities as shown in Fig. 14(b). The optimum range of operation centers at about 410 nm.

The switch may also be used as a polarization filter, i.e., an arbitrarily polarized light beam will be split into two components: one parallel (transmitted) and the other perpendicularly polarized (reflected) to the  $c$  axis. The resulting degrees of polarizations for the transmitted and reflected beams are shown in Fig. 14(c). The operation regime falls into the wavelength range, where both beams have high degrees of polarization as shown in the plot of the polarization selectivity in Fig. 14(d).

Although the maximum theoretical values are not reached for switch gain and selectivity, the concept for a beam switch based on a two-color distributed Bragg reflector has been clearly demonstrated.

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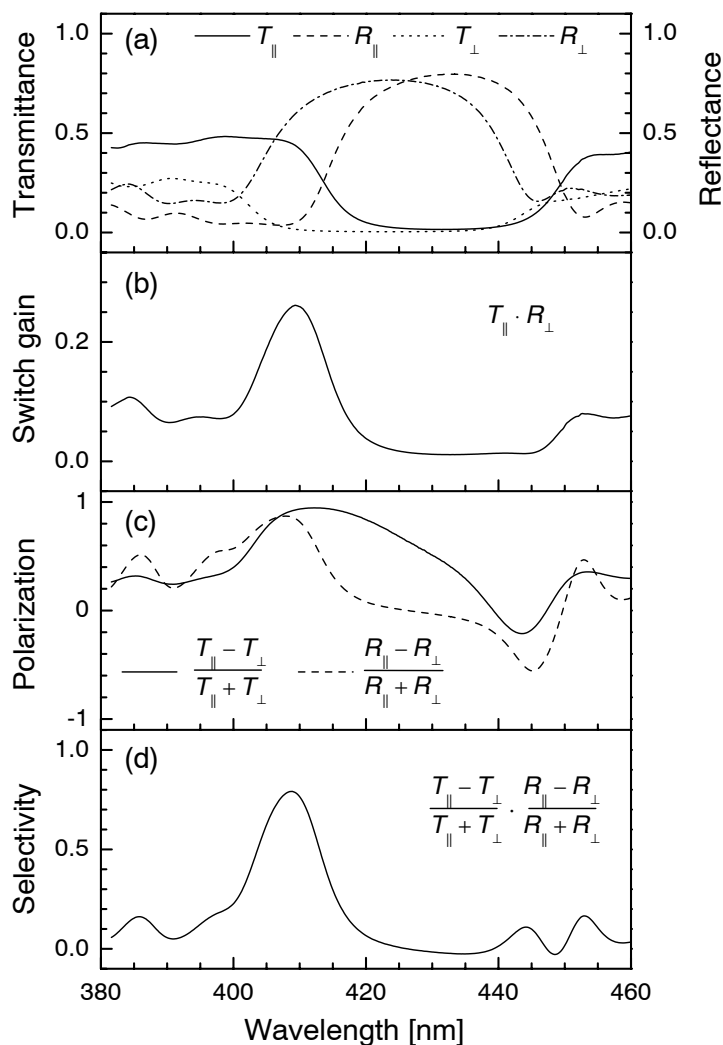


Fig. 14. (a) Transmittance and reflectance versus wavelength for polarizations parallel ( $T_{\parallel}$ ,  $R_{\parallel}$ ) and perpendicular ( $T_{\perp}$ ,  $R_{\perp}$ ) to the  $c$  direction. The shift in the stop band is clearly visible. (b) Switch gain versus wavelength. (c) Degree of polarization for transmitted and reflected beam. (d) Selectivity versus wavelength.