Direct wafer bonding of GaN on AlN through the optimization of Chemical Mechanical Polishing

K. Pan,[1+] K. Huynh,[1] M. Li,[2] Y. Ge,[2] T. Fisher,[2] Y. Hu,[2] and M. S. Goorsky[1]
[1]Department of Materials Science and Engineering, University of California Los Angeles, Los Angeles, California, 90095, USA
[2]Department of Mechanical and Aerospace Engineering, University of California Los Angeles, Los Angeles, California, 90095, USA

Optimization of surface preparation and interfacial characterization of direct wafer bonded GaN to AlN are presented in this study. In particular, the Ga face of the GaN wafer was bonded to the N face of the AlN wafer. The as received Ga-face of GaN substrates showed <1 nm roughness while the N-face AlN had a starting roughness of ~3 nm RMS. The N-face of the AlN was successfully polished to <1 nm RMS roughness suitable for direct wafer bonding using chemistry based on our previous work with GaN CMP [1]. For bonding, 2" GaN (Unipress) and 2" AlN (Hexatech) were bonded using standard cleaning and immersion in a $(NH_4)_2S$ solution. The samples were rinsed, dried and pressed Ga- to N-face (AlN) under moderate pressure (~50 kPa) and room temperature bonding was initiated. A significant fraction of the surfaces bonded, except for a couple of triangular regions associated with growth sector boundaries in the GaN. Subsequent annealing up to 800 C° was performed to strengthen the bond and to test the structure for high temperature stability. Similar coefficient of thermal expansion between GaN and AlN at high temperatures allows for high temperature annealing without debonding or cracking. The GaN substrate was then grinded and also subject to CMP to < 1um for transmission electron microscopy and time-domain thermal reflectance measurements of the bonded interface.

High resolution transmission electron microscopy shown in Figure 1 reveals complete crystallinity across the interface. However, only a ~1.5 nm interfacial region is observed, which is suspected to be caused by reconfiguration of the interface after a total anneal of 350 °C 22 hours, 600 °C 1 hour, and 800 °C 1 hour. No thicker amorphous or oxide interfacial layer commonly found in other bonding methods (surface activated bonding, plasma treatment, or other interfacial layers) [2-5] are observed in this study. Preliminary thermal boundary conductance measurements via time domain thermal reflectance have been measured and will be reported.

[1] S. Hayashi, et al., J. Electrochem. Soc., 155(2), p.H113 (2007)
[2] M.E. Liao, et al., ECS Trans., 86(5), 55 (2018)
[3] V. Dragoi, et al., ECS Trans., 86(5), 23 (2018)
[4] Y. Xu, et al., Ceram. Int., 45, 6552 (2019).
[5] F. Mu, et al., Appl. Surf. Sci., 416, 1007 (2017)

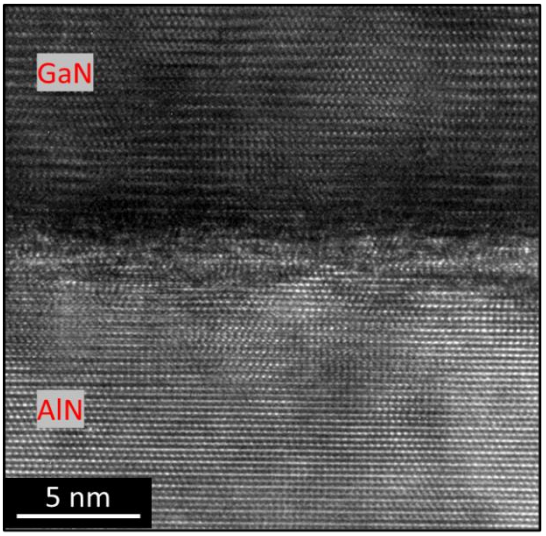

Figure 1 HRTEM of the wafer bonded GaN-AlN interface. ~1.5 nm interface can be observed due to reconfiguration of atoms after high temperature annealing.

[+]Author for correspondence: kaichengpan@g.ucla.edu