Tailoring growth interfaces of virtual substrates for power electronics

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Power electronics materials are poised to play a critical role in fulfilling next generation energy needs, with up to 90% of future energy demand predicted to flow through power electronics at some point.[1] $Al_xGa_{1-x}N$ ranks high among candidate materials, having bipolar dopability, thermal and chemical stability and an ultra-wide bandgap. However, AlGaN growth is limited by a lack of lattice-matched substrates, ultimately stunting material quality at higher thicknesses needed for power electronics applications. Further, high power applications increasingly call for fully vertical device structures, necessitating a conductive substrate. [1] Recently our group identified the (111) plane of TaC as a conductive surface lattice-matched to $Al_{0.55}Ga_{0.45}N$, taking inspiration from prior work of AlN and GaN binaries on carbide and boride substrates. [2,3,4]

In this talk we demonstrate the growth of (111)-oriented TaC by RF sputtering. We investigate the interface of TaC with sapphire and SiC substrates and identify means to suppress competing Ta_2C nucleation in order to stabilize (111)-oriented TaC. Potential stacking sequences are identified with respect to crystal structure and observed twinning in the TaC films. We next assess structural changes and film recrystallization that results from face-to-face annealing of TaC thin films at high temperatures above 1500 ºC. Changes to grain structure and domain size are assessed by x-ray diffraction and surface morphology is explored using atomic force microscopy. **Fig 1** shows significant improvements to in- and out-of-plane strain following annealing along with the formation of terraced step edges at the film surface. Strain as a function of material composition and thickness is considered, as this may play a major role in future nucleation of AlGaN layers.

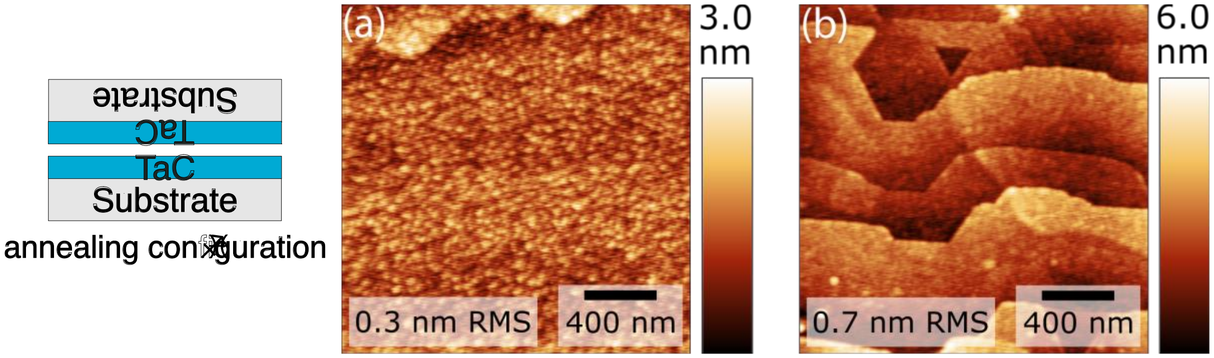

Figure 1 Atomic force microscopy of TaC films (a)before annealing and (b) after annealing at 1600 ºC in a face-to-face configuration, as illustrated in the schematic at left.

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[2] D. M. Roberts et al 2022, https://arxiv.org/abs/2208.11769
[3] T. Aizawa et al 2008, *J Crys Growth* 310, 1 22
[4] R. Liu et al 2002, *Appl. Phys. Lett.* 81, 3182-3184

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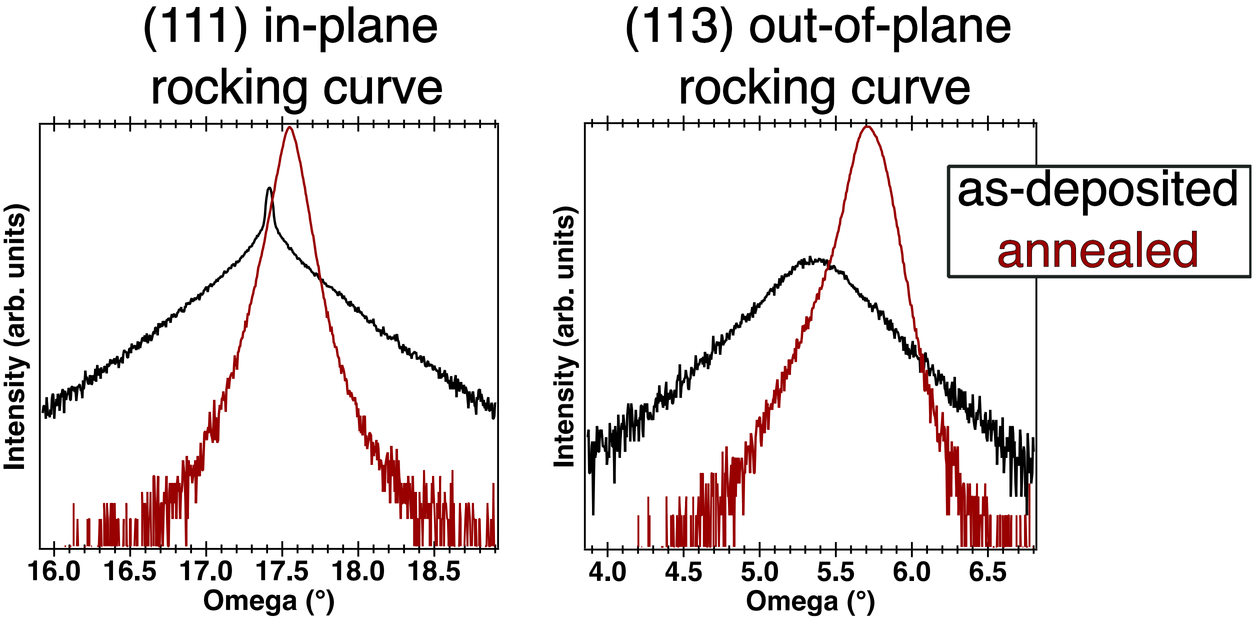

X-ray diffraction rocking curves for in-plane (left) and out-of-plane (right) faces of TaC thin films before and after annealing. Following anneal, peaks shift to higher omega and full width at half max reduces significantly.