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Resolving Atomic Scale Chemistry and Structure at NO and Ba Passivated SiC/SiO_2 Interfaces

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Silicon carbide has become a commonly used wide-bandgap material for power devices. A major challenge for SiC MOSFET device processing has been to reduce the density of trap states at the SiC/SiO_2 interface, which greatly reduces the inversion-layer field effect mobility, μ_{FE}, Nitric oxide (NO) annealing is commonly performed to passivate the SiC/SiO_2 interface and reduce the interface trap density. A new method for increasing μ_{FE} involves depositing a layer of Ba at the interface which has been shown to produce μ_{FE} values up to 85 $\frac{cm2}{V*s}$ [1], more than double that with the NO anneal. The impact of the SiC/SiO_2 interface on μ_{FE} has driven research towards studying the transition layer between SiC and SiO_2 [2]. Although studies report chemical segregation of N in NO annealed devices [3], the influence of Ba is unreported. Further, the influence of interfacial treatments on the atomic structure remains unclear even for NO annealed devices.

In this talk, we will examine the impact of interfacial treatments on the SiC/SiO_2 interface using scanning transmission electron microscopy (STEM), electron energy-loss spectroscopy (EELS) and energy dispersive X-ray spectroscopy (EDS). From high angle annular dark-field (HAADF) imaging, we clearly resolve the SiC/SiO_2 interface for Ba and NO treated samples, Figure 1 (a-b). We will discuss Ba and NO interfaces, emphasizing the differences in the transition layer between each sample. Although HAADF STEM proves useful for Z contrast imaging, many ambiguities at interfaces remain without support from spectroscopy[4]. By employing EDS we will resolve such ambiguities and reveal the chemical makeup of each interface, Figure 1 (c,d). We will show that EDS reveals information at the interface that would be hidden by relying on HAADF imaging alone especially in the case of NO annealed devices.

We will then discuss the effects of interfacial chemistry on the atomic structure at the interface. Using Revolving STEM (RevSTEM) to correct drift and image distortion in STEM images, we obtain images with atom columns at highly accurate positions [5-7]. By measuring the atom column-to-atom column distances, we generate strain maps for each sample [8]. We will compare these results with geometric phase analysis (GPA) to address the strain states using multiple methods. For NO, there is a tensile strain within SiC at the SiO_2/SiC interface, Figure 2. The Ba interlayer sample, however, exhibits no observable strain relative to the bulk SiC structure. We will discuss the bonding configuration and consequences of this lattice strain on electrical properties [9].

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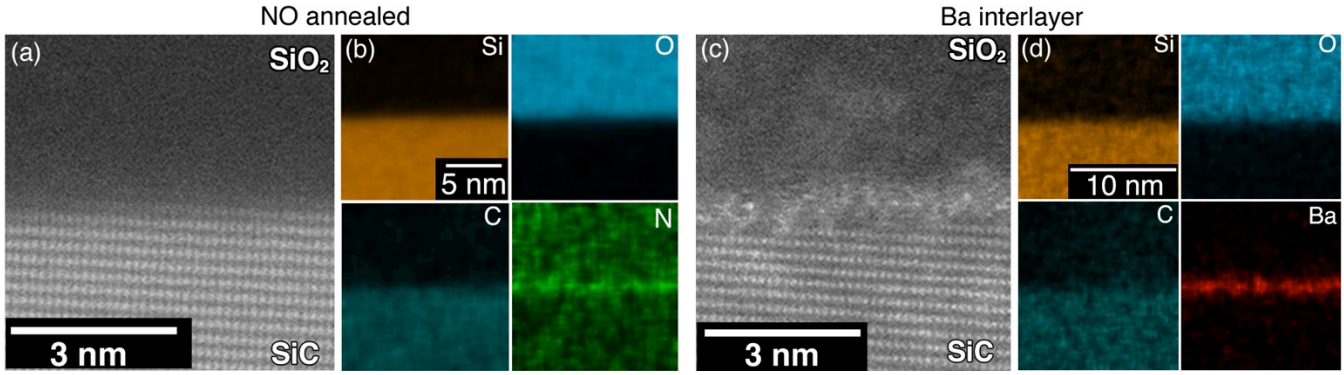

Figure 1: HAADF STEM of the SiC/SiO_2 interface when NO (a) and Ba (c) passivated. EDS maps from NO (b) and Ba (d) devices with elemental X-ray maps for all elements observed during acquisition.

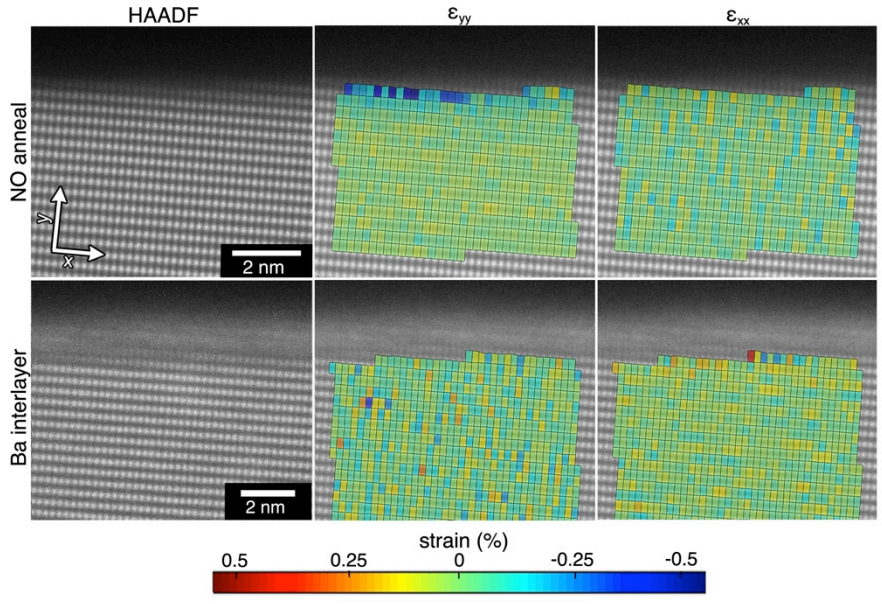

Figure 2: RevSTEM frame averaged series for both Ba (bottom left) and NO (top left) samples. Strain maps are overlaid on the RevSTEM images with values corresponding to the colorbar.

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