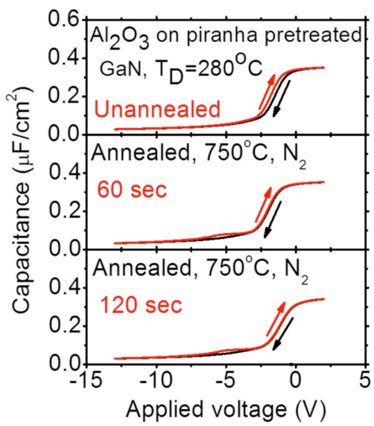
Atomic Layer Deposition – Research Highlights

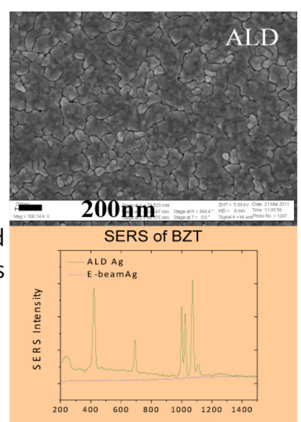
Surface Pretreatments Critical to High-κ Dielectric/III-N Semiconductor Interface

ESTD researchers have developed a method to improve the interface of high-κ dielectrics with III-N semiconductors such as GaN and AlGaN. Such interfaces are of growing importance for high-power RF and the emergent normally-off power switch development efforts. A combination of ex situ wet chemical and in situ plasma-assisted processes has been shown to result in thin, ultra-smooth high-κ Al_2O_3 and HfO_2 dielectrics that exhibit markedly lower oxide and interface state trap densities, and on-state gate leakage densities of $<1\times10^{-8}$ A/cm^2. These processes and resulting interfaces are now being integrated with enhancement-mode power transistor designs to assess performance and reliability.



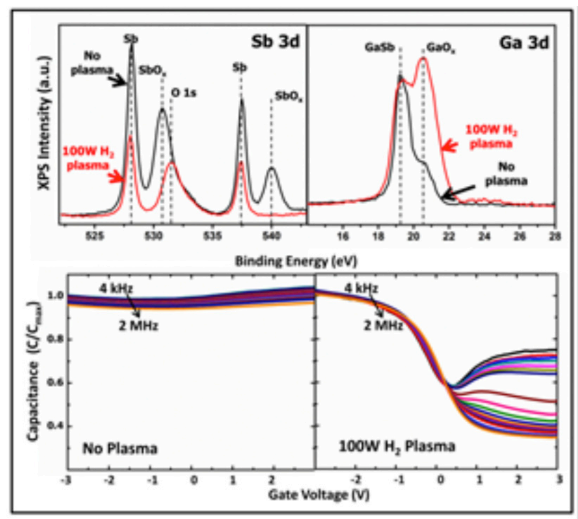
ALD-Grown Plasmonic Ag Metamaterial

Naturally patterned and optically active Ag thin films have been deposited using plasma-enhanced atomic layer deposition (PEALD). These Ag films are a metamaterial that exhibits plasmonic behavior due to the unique mosaic structure, consisting of 2D Ag islands separated by air gaps (<4 nm). Since these films are conformal and capable of covering high aspect ratio structures, we formed closely spaced nanowire/Ag composite arrays, thereby enhancing the Raman response of these structures by 10^8–10^9. Due to their low-temperature deposition and conformality, they also enable the formation of plasmonic fabrics. Electric field simulations have shown that high electric fields form in and above the air gaps, resulting in this strong plasmonic behavior.



Surface Modification Using In Situ Hydrogen Plasma Prior to the Atomic Layer Deposition of Al_2O_3 on GaSb

An in situ hydrogen plasma pretreatment process has been used to prepare low-defect interfaces between GaSb substrates and high-κ Al_2O_3 gate oxide films deposited by atomic layer deposition (ALD). High-mobility, narrow-bandgap semiconductors such as GaSb are of great interest for high-speed, low-power digital electronics; however, realization of advanced devices requires high-quality semiconductor/dielectric interfaces, which can be difficult to achieve given the thick, complex oxide native to GaSb surfaces. By preceding dielectric ALD by in situ hydrogen plasma exposure, the native GaSb oxide is replaced by a thin Ga_2O_3 interlayer that provides significantly improved electrical characteristics. The plasma pretreatment eliminates the need for wet chemical etches and makes it a promising approach for achieving high-performance Sb-based devices.



Atomic Layer Deposition of High-κ Oxides and Nanolaminates

High-κ dielectrics are an essential component of aggressively scaled III-V and graphene-based devices to enable operation in the terahertz regime, to improve channel mobility, and to reduce leakage current of traditional SiO_2 gates while maintaining high gate capacitance and charge control of the channel. Atomic layer deposition (ALD) offers the possibility to deposit ultrathin, conformal oxides with precise thickness and uniformity over large areas. Moreover, ALD has the capability to deposit nanolaminates of two or more dielectrics such as TiO_2 and Al_2O_3 that have unique properties. This allows tailoring of the bandgap and dielectric constant of the resulting oxides.