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Electron effective mass determination across a β-$(Al_{0.2}Ga_{0.8})_2O_3$//β-Ga_2O_3 interface by Kramers-Kronig analysis

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Gallium-oxide in its monoclinic phase (β-Ga_2O_3) is a very promising material in high power electronic devices and photodetectors due to its wide bandgap (~4.8 eV) and a potentially high breakdown field (~8 $MV.cm^{-1}$) [1]. Interestingly, alloying β-Ga_2O_3 with aluminum-oxide (Al_2O_3) to form a β-$(Al_xGa_{1-x})_2O_3$ semiconductor offers new opportunities as it broadens device design possibilities and enhances the electronic properties as it is expected to cover even larger deep ultraviolet region and electronics with even higher critical field strength. Moreover, in β-$(Al_xGa_{1-x})_2O_3$/β-Ga_2O_3 heterostructures, a two-dimensional electron gas can be achieved through modulation doping with high channel mobilities at room temperatures and even reported higher mobilities at low temperatures [2]. One of the main parameters that drives the Drude electron mobility in a crystal is the effective mass and its experimental determination and variation in β-$(Al_xGa_{1-x})_2O_3$/β-Ga_2O_3 heterostructures is yet to be explored.

In this study we report the measurement of the dielectric constant and direct measurements of electron effective mass across a β-$(Al_{0.2}Ga_{0.8})_2O_3$/β-Ga_2O_3 interface using monochromated electron energy-loss spectroscopy combined through Kramers-Kronig analysis. In addition, this study further investigates the defects present at the interface and how they can affect electron mobility.

Figure 1.a shows a HAADF-STEM image of the β-$(Al_{0.2}Ga_{0.8})_2O_3$/β-Ga_2O_3 interface within multiple EELS point scans (yellow dots) from which low loss EELS spectra were utilized to measure the variation of the plasmon energy peaks. Figure 1.b shows plasmon peak energy variations across the interface that have been extracted from the EELS point scans. A plasmon peak shift of about 100 meV was observed, suggesting an electron accumulation along the interface. Moreover, using Kramers-Kronigs calculations, a decreasing mean value of the effective mass is observed as we move from β-$(Al_{0.2}Ga_{0.8})_2O_3$ to β-Ga_2O_3 substrate which is in good agreement with the predictions in the literature [3]. We observe a local dip of the effective mass in the vicinity of the interface suggesting a higher electron mobility locally at the interface.

This work provides direct calculations of the electron effective mass variation in β-$(Al_{0.2}Ga_{0.8})_2O_3$/β-Ga_2O_3 heterostructures, meaningful for the understanding of electron channel mobility in AlGaO/GaO based devices.

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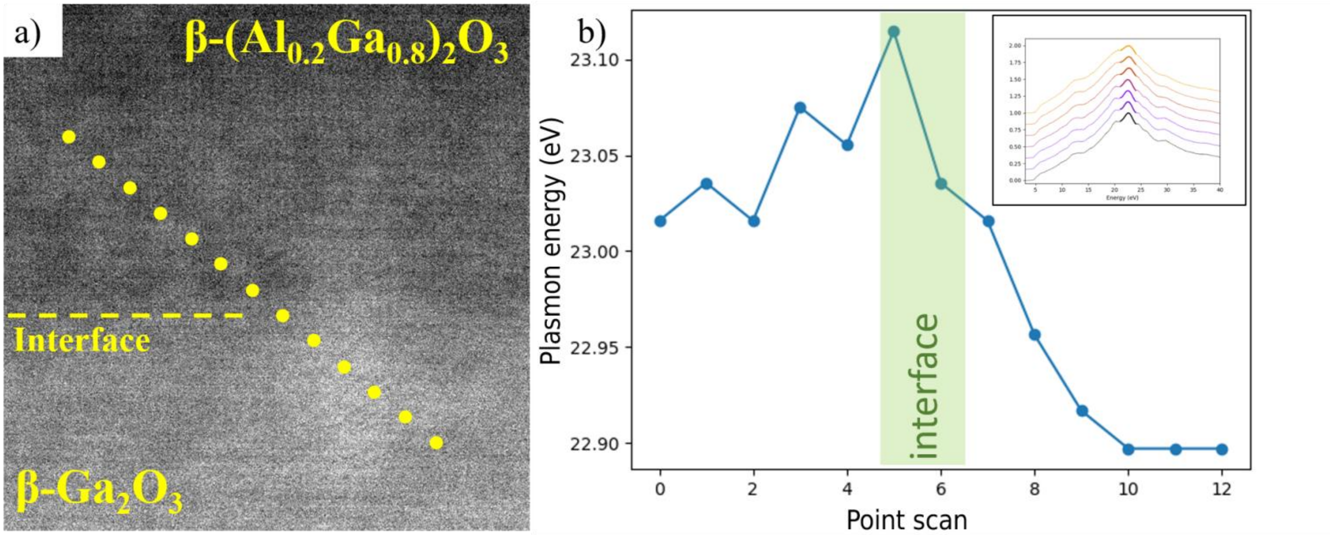

Figure 1. (a) HAADF-STEM image of the β-(Al0.2Ga0.8)2O3/β-Ga2O3 interface within multiple EELS point scans (yellow dots) from which low loss EELS spectra were utilized to measure the variation of the plasmon energy peaks. (b) Plasmon shift variation across the β-(Al0.2Ga0.8)2O3/β-Ga2O3 interface obtained by fitting the plasmon peaks extracted from the EELS point scans as shown in the insert.

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