Student Paper

Improved Properties of Atomic Layer Deposited HfO_2 Dielectrics on GaSb Substrates with NH_4F Treatment

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III-V compound semiconductor materials have become increasingly important alternative channel materials to silicon, due to the high carrier mobility [1]. GaSb is especially favorable for the p-type MOS application, because of its high hole mobility [2]. However, high interface trap density (Dit) has limited the wide use of III-V MOS devices [3]. Many methods have been proposed to improve the interfacial properties of III-V MOS devices [4,5]. In this work, we investigated the effects of NH_4F solution treatment on the interfacial and electrical properties of HfO_2/GaSb gate stacks. It is found that NH_4F solution treatment is superior to the traditional $(NH_4)_2S$ solution treatment.

Starting substrates were Te-doped (100)-oriented n-type GaSb wafers with a doping concentration of ~10^{17} cm^{-3}. The substrates were first degreased by sequential immersion for 5 min each in acetone, ethanol, and isopropanol, and then cleaned with 9% HCl for 1 min. After that, surface passivation treatments were performed using 20% NH_4F solution for 4 min. Control samples were treated with 20% $(NH_4)_2S$ solution. An HfO_2 dielectric layer (~5.5 nm) was atomic-layer-deposited on GaSb substrates at 200 °C with Tetrakis(ethylmethylamino)hafnium (TEMAH) and water as precursors. Finally, Al was evaporated and patterned to form MOS capacitors (MOSCAPs). Back metal contacts of Ti/Au were also deposited. High-resolution X-ray photoelectron spectroscopy (XPS) was performed to confirm the effects of fluorine passivation. Capacitance-voltage (C-V), conductance-voltage (G-V) and gate leakage current-voltage (J-V) characteristics were recorded using an Agilent B1500A semiconductor device analyzer and a Cascade Summit 11000 AP probe system.

Fig. 1(a) and (b) show XPS F 1s spectra of the GaSb surfaces passivated with $(NH_4)_2S$ solution and NH_4F solution, respectively. The F 1s peak, which cannot be observed in the spectrum of the samples treated with $(NH_4)_2S$ solution, is visible at ~684 eV for the samples passivated with NH_4F solution. This indicates that the surface is passivated by fluorine effectively. Fig. 2 shows the multi-frequency C-V characteristics of GaSb MOSCAPs passivated with $(NH_4)_2S$ and NH_4F solutions. The frequency dispersion in the accumulation region is reduced significantly by passivation with the NH_4F solution instead of the $(NH_4)_2S$ solution, which indicates that the interfacial properties are greatly improved using the NH_4F solution [6]. The gate leakage current density for samples treated with NH_4F solution is reduced by nearly two orders of magnitude, compared with that of samples treated with $(NH_4)_2S$ solution, as shown in Fig. 3. Dit distribution is also determined using the conductance method, as plotted in Fig. 4. Compared with the samples treated with $(NH_4)_2S$ solution, Dit is reduced by 31% for the samples treated with NH_4F solution, which is consistent with the smaller frequency dispersion of the samples treated with NH_4F solution (see Fig. 2). The reduced Dit may be attributed to the reduction of dangling bonds, which are passivated by fluorine.

In summary, surface passivation with NH_4F solution was found to be a promising method to improve the properties of GaSb MOS devices. Frequency dispersion, gate leakage current and Dit are all reduced for samples treated with NH_4F solution, compared with those treated with $(NH_4)_2S$ solution.

Acknowledgments

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References

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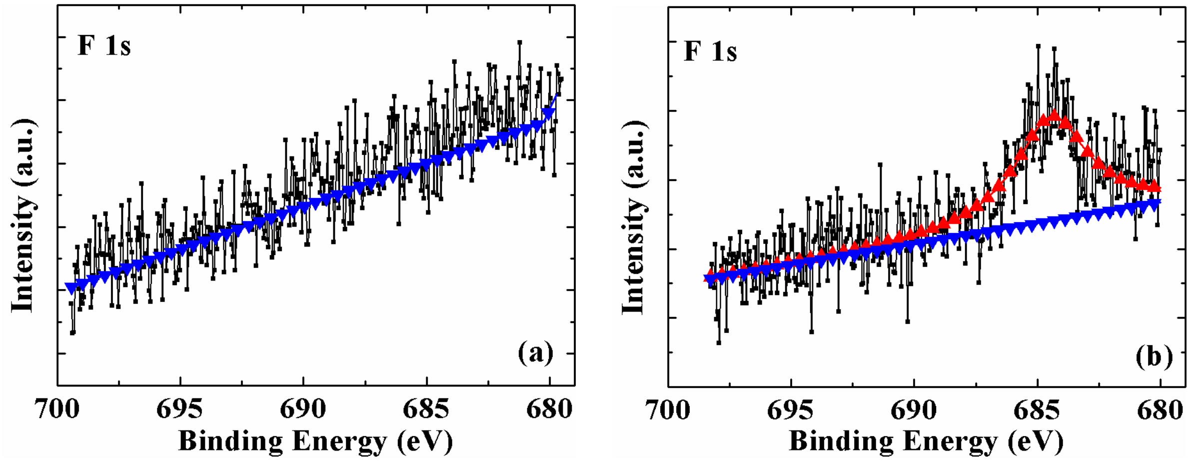

Fig. 1. XPS F 1s spectra of GaSb MOSCAPs passivated with (a) $(NH_4)_2S$ solutions and (b) NH_4F solutions.

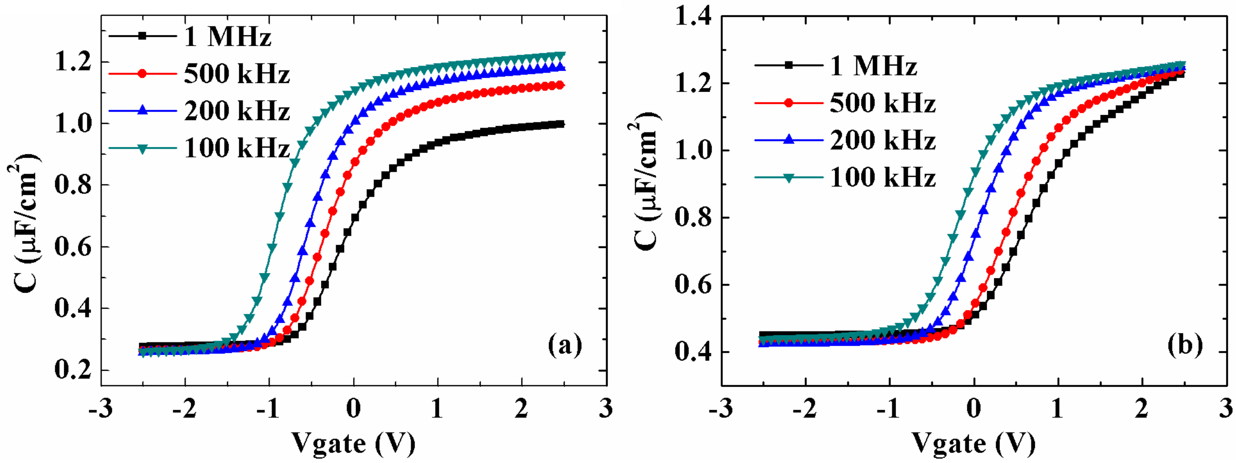

Fig. 2. Multi-frequency C-V characteristics of GaSb MOSCAPs passivated with (a) $(NH_4)_2S$ solutions and (b) NH_4F solutions.

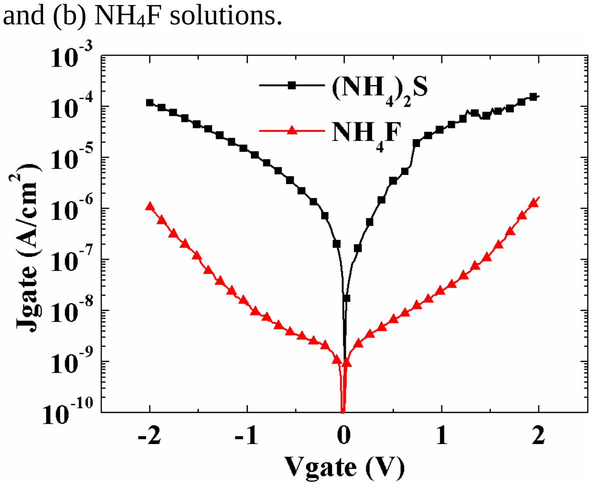

Fig. 3. Comparison of gate leakage current characteristics of MOSCAPs passivated with $(NH_4)_2S$ and NH_4F solutions.

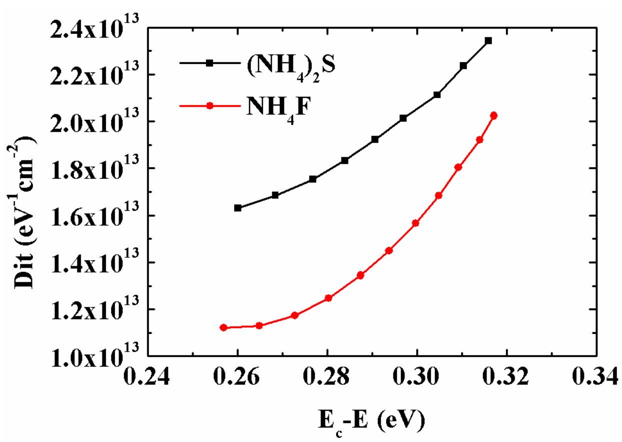

Fig. 4. Dit distributions of MOSCAPs passivated with $(NH_4)_2S$ and NH_4F solutions.