Sulfur Passivation Enhancement for GaSb MOS Devices by Adding H_2O_2 to $(NH_4)_2S$ Solution

Zhen Tan[a], Lianfeng Zhao[a], Zhuohuang Zhang[a, b], Bolin Shan[a], Jing Wang[a] and Jun Xu[a]

[a] Institute of Microelectronics, Tsinghua University, P. R. China
[b] School of Optoelectronics, Beijing Institute of Technology, P. R. China

GaSb has attracted lots of attention for the p-type MOS application, because of its high hole mobility.[1,2] However, high interface trap density (Dit) has limited its wide application.[3] Sulfur passivation with $(NH_4)_2S$ solution is believed to be a promising method to improve the interfacial properties of GaSb MOS devices. However, the effects of sulfur passivation by traditional $(NH_4)_2S$ solution should be further improved. In this work, we investigated the H_2O_2 enhanced $(NH_4)_2S$ solution treatment on GaSb MOS devices by adding H_2O_2 to $(NH_4)_2S$ solution. It is found that after adding H_2O_2 to $(NH_4)_2S$ solution, the sulfur passivation effect is superior to the traditional $(NH_4)_2S$ solution method.

Figure 1 shows the schematic cross section of the GaSb MOS capacitor structure. Te-doped (100)-oriented n-type GaSb wafers with a doping concentration of ~10^{17} cm^{-3} were used as starting substrates, which 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, sulfur passivation with H_2O_2 enhanced $(NH_4)_2S$ solution were performed for 15 min. H_2O_2 enhanced $(NH_4)_2S$ solution were prepared by adding 7.5 mL 35% H_2O_2 to 150 mL 20% $(NH_4)_2S$ solution. Due to the oxidability of H_2O_2, the color of the H_2O_2 enhanced $(NH_4)_2S$ solution is different from the traditional 20% $(NH_4)_2S$ solution, as shown in Figure 2. After sulfur passivation treatment, 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. Control samples treated with traditional 20% $(NH_4)_2S$ solution were fabricated for comparison. 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.

Figure 3 compares the C-V characteristics of the GaSb MOSCAPs passivated with the H_2O_2 enhanced $(NH_4)_2S$ solution and the traditional $(NH_4)_2S$ solution. The reduced capacitance in the accumulation region for the samples treated with H_2O_2 enhanced $(NH_4)_2S$ solution might be due to the formation of a sulfur layer. The gate leakage current density for samples treated with H_2O_2 enhanced $(NH_4)_2S$ solution is reduced by more than two orders of magnitude, compared with that of samples treated with traditional $(NH_4)_2S$ solution, as shown in Figure 4. Figure 5 presents the typical measured parallel G_p/ω versus frequency curves for different gate biases of the MOSCAPs treated with H_2O_2 enhanced $(NH_4)_2S$ solution. The peak shift indicates the Fermi level unpinning over the energy gap. Dit distribution is also determined using the conductance method,[4] as plotted in Figure 6. Compared with the samples treated with traditional $(NH_4)_2S$ solution, Dit is reduced by 29.4% for the samples treated with H_2O_2 enhanced $(NH_4)_2S$ solution. The reduced Dit might be due to the sulfur passivation enhancement effects of adding H_2O_2 into $(NH_4)_2S$ solution.

In summary, sulfur passivation is found to be enhanced by adding H_2O_2 to $(NH_4)_2S$ solution, which can improve the properties of GaSb MOS devices, such as the gate leakage current and interface trap density.

Acknowledgments

This work was supported in part by the State Key Development Program for Basic Research of China (No. 2011CBA00602) and by the National Science and Technology Major Project (No. 2011ZX02708-002).

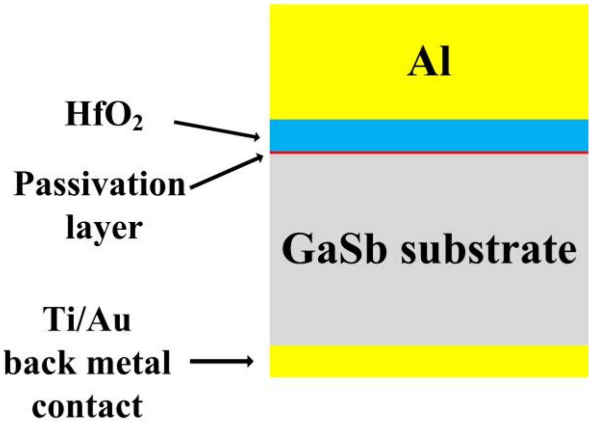

Figure 1. Cross-sectional schematic of the GaSb MOS capacitors.

Figure 2. Comparison of the $(NH_4)_2S$ Solution

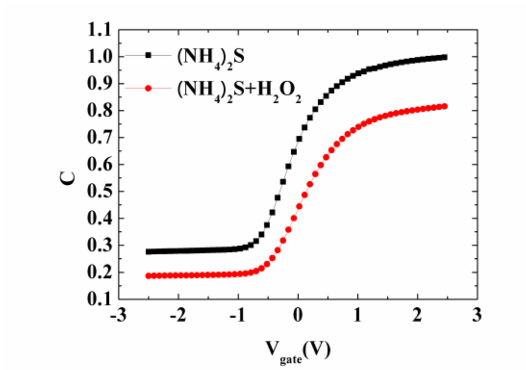

Figure 3. C-V characteristics of the measured GaSb MOSCAPs at 1MHz.

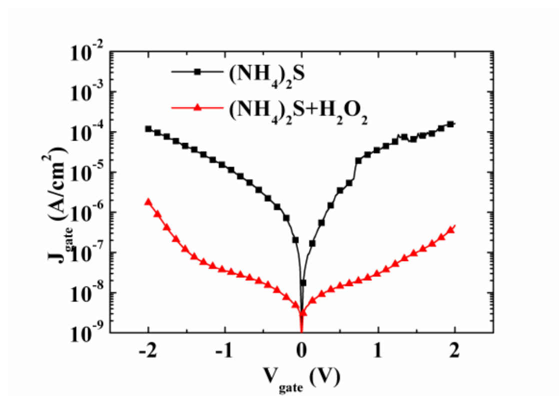

Figure. 4. Gate leakage current characteristics of the measured GaSb MOSCAPs.

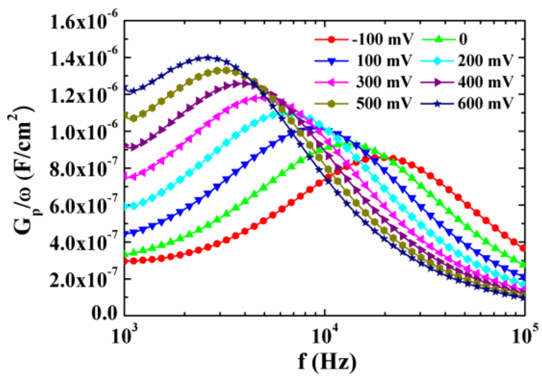

Figure 5 Typical measured parallel G_p/ω versus frequency characteristics for different gate bias voltages of the measured GaSb MOSCAPs.

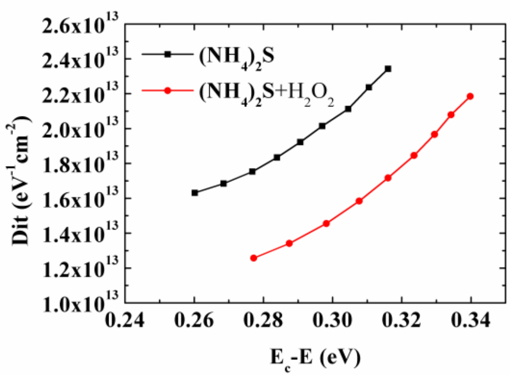

Figure 6. Dit distributions of the measured GaSb MOSCAPs.

[1] J. A. del Alamo, *Nature*, vol. 479, pp. 317-323, 2011.

[2] Z. Yuan, A. Nainani, B. R. Bennett, J. B. Boos, M. G. Ancona, and K. C. Saraswat, *Appl. Phys. Lett.*, vol. 100, pp. 143503-4, 2012.

[3] A. Ali, H. S. Madan, A. P. Kirk, D. A. Zhao, D. A. Mourey, M. K. Hudait, R. M. Wallace, T. N. Jackson, B. R. Bennett, J. B. Boos, and S. Datta, *Appl. Phys. Lett.*, vol. 97, pp. 143502-3, 2010.

[4] E.H. Nicollian, A. Goetzberger, *Bell Syst.Tech. J.*, vol 46 pp. 1055–1133, 1967.