Dry Etching of Perovskite Oxides for High Performance Electronic Device Applications

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Recently, a wide bandgap perovskite material, $BaSnO_3$ (3.1eV) have emerged showing electron mobility and high carrier concentration.[1] It has also been proposed that using such material as a channel material, with proper design of cap layers, such as $BaTiO_3$ and $SrTiO_3$ to form heterostructures, could achieve high-performance devices comparing to the state of the art III-N technologies.[2] There is, however, little systematic study on the etching of perovskite oxides $BaSnO_3$, $BaTiO_3$ and others. The establishment of etching processes of this material system at nanometer scales is important on development of high performance perovskite oxide based devices.

In this work, we report the etching studies of epitaxially-grown perovskite oxide $BaSnO_3$ and $BaTiO_3$ thin films using an inductively coupled plasma reactive ion etching (ICP-RIE) system. The results show that Cl-based plasma chemistries (BCl_3/Ar) gave a higher etch of $BaSnO_3$ rate than the F-based plasma chemistries (CF_4/Ar) under the same ion energy. Also, the F-based chemistry essentially doesn't etch $BaTiO_3$, e.g. < 1 nm/min. This is mostly due to that etching products of F-chemistries are less volatile than the case of Cl-based chemistries. It was also found that the Cl-based plasma produced a time-independent and high etch rate with smooth etched surface. For the Cl-based plasma, the etch rate dependence study suggests that the etch rates increase with the increase of the plasma density and ion energy (Fig. 1). The etch rate and etched surface smoothness were characterized by AFM and SEM (Fig. 2). SEM micrograph also suggests a fairly smooth sidewall roughness. A $BaTiO_3$/$BaSnO_3$ heterostructure field effect transistor with a gate length of 1.5 μm was fabricated using the established processes to etch $BaTiO_3$ for contact vias and to etch $BaSnO_3$ for mesa isolation. Excellent device characteristics with saturation current density of I_d = 287 mA/mm, transconductance of g_m = 91 mS/mm, and threshold voltage of V_{th} = -2.6 V (Fig. 3) were achieved. The etching results in this work will enable the further development of high performance perovskite oxide heterostructure devices.

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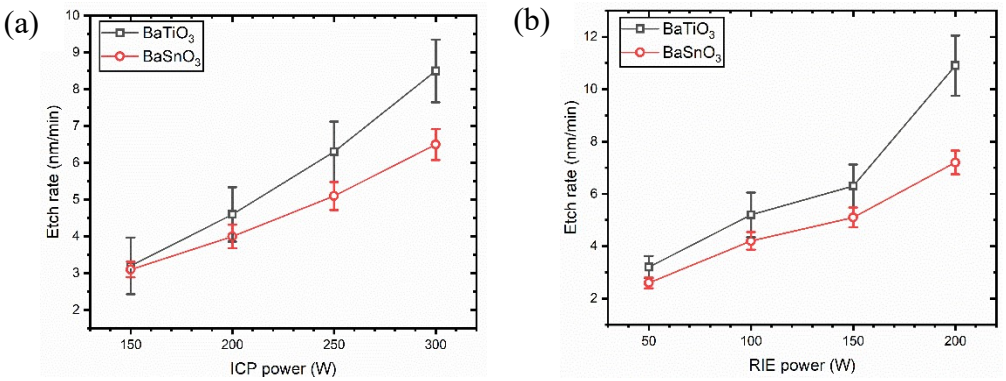

Figure 1: Etch rate of $BaTiO_3$ and $BaSnO_3$ (a) vs ICP power at 150 W RIE power, (b) vs RIE power at 250 W ICP power. Etching condition: $P_{chamber}$ = 10 mTorr, Flow rate (BCl_3/Ar) = 40/10 sccm.

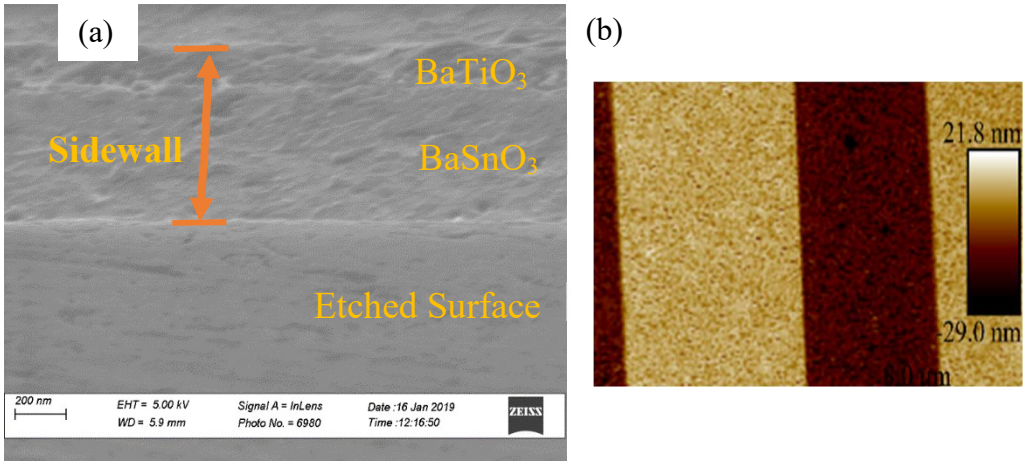

Figure 2: (a) SEM micrograph of the etched surface and sidewall of $BaTiO_3$ and $BaSnO_3$ heterostructure layer. (b) AFM micrograph of the etched and non-etched surface.

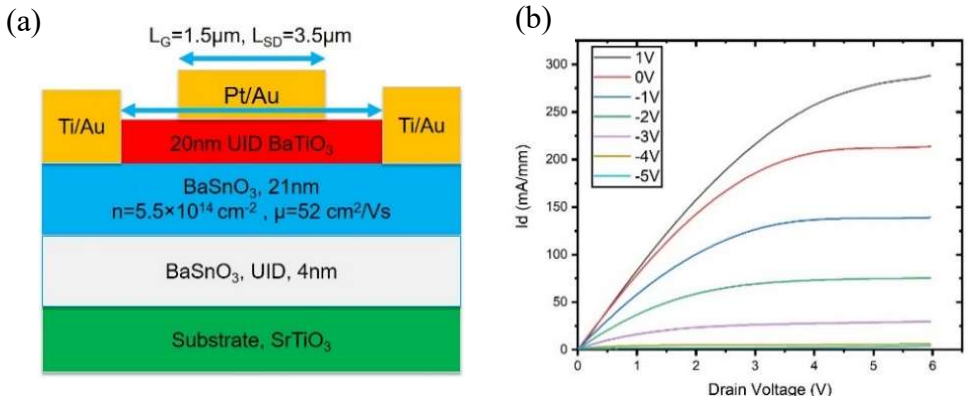

Figure 3: (a) Schematic of the $BaTiO_3$/$BaSnO_3$ device structure. (b) Family I-V characteristics of a L_g = 1.5 μm $BaTiO_3$/$BaSnO_3$ heterostructure device.