Development of 400°C operational relaxor ferroelectric based thin-film capacitor with exceptionally high stability

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High-temperature operating electronic devices are indispensable for geothermal, automotive, space and aviation applications. SiC and diamond based transistors and diodes are capable of operating at 500°C. In contrary, the capacitors can operate up to 175°C only and are bulky too. Therefore, it is necessary to develop monolithic thin-film capacitors that can operate at least up to 400°C. In the previous meeting, we demonstrated (1-x)[$BaTiO_3$] - x[$Bi(Mg_{2/3}Nb_{1/3})O_3$]（BT-BMN）relaxor ferroelectric epitaxial thin-film capacitor that functions up to 400°C [1]. However, the high-temperature stability of relative dielectric constant (ε_r) was poor especially, at 25 – 100 °C regime. Here, we show the exceptionally-high temperature stability of Ta doped BT-BMN compositionally engineered polycrystalline thin-film stacked capacitor.

In the epitaxial capacitor, BT-BMN films were deposited using pulse laser deposition method. A significant out-diffusion of Bi was observed, in x-ray photoelectron spectroscopy analysis, on post-growth annealed BT-BMN surface. This caused the increase of dielectric loss and dielectric constant at high-temperatures that eventually lowered the temperature stability of the capacitor. To suppress the Bi out-diffusion Ta doped (max. 3 mol%) BT-BMN layer was introduced in the film at regular spacing. It significantly suppressed the Bi out-diffusion and improved the temperature stability of ε_r and also the leakage current. However, the dielectric constant was dropped around room temperature. As a counter measure, we altered the composition ratio of BT and BMN film to shift the ε_r peak-maximum towards low temperature region according to the results of bulk ceramics. Figure 1a depicts the compositionally engineered Ta doped BT-BMN film stack. Figure 1b shows the dielectric constant and dielectric loss as a function of temperature. Note that the dielectric constant exceeds 400 and the temperature stability is below 4% in 23-400°C range at 50 kHz.

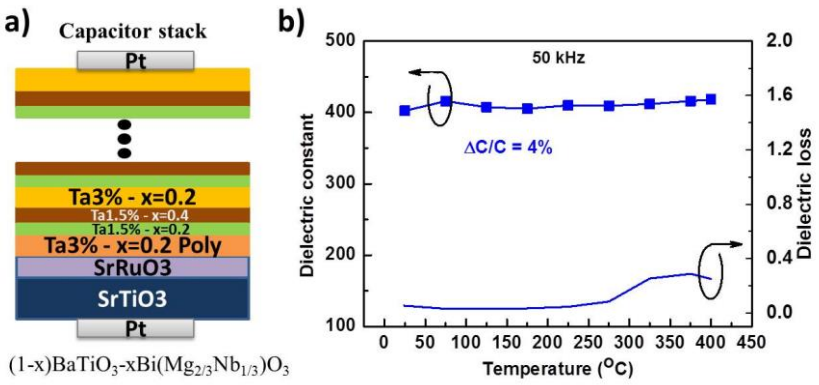

Fig. 1 (a) Schematic of Ta doped BT-BMN capacitor and (b) temperature dependency of dielectric constant and dielectric loss at 50kHz.

[1] S. Kumaragurubaran et al. 75th JSAP-Fall Annual Meetings, 18p-A9-2 (2014).