Abstract:

We report a fully transparent thin-film transistor utilizing a La-doped BaSnO$_3$ channel layer that provides a drain current of 0.468 mA/µm and an on-off ratio of $1.5 \times 10^8$. The La-doped BaSnO$_3$ channel is grown on a 100-150 nm thick unintentionally doped BaSnO$_3$ buffer layer on a (001) MgO substrate by molecular-beam epitaxy. Unpatterned channel layers show mobilities of 127-184 cm$^2$V$^{-1}$s$^{-1}$ at carrier concentrations in the low to mid $10^{19}$ cm$^{-3}$ range. The BaSnO$_3$ is patterned by reactive ion etching under conditions preserving the high mobility and conductivity. Using this patterning method, a sub-micron-scale thin film transistor exhibiting complete depletion at room temperature is achieved.

Summary of Research:

In summary, a fully transparent submicron TFT based on BaSnO$_3$ has been fabricated with a high drain current and on/off current ratio. This breakthrough is made possible by (1) high mobility bare films in combination with (2) the development of a micrometer-scale etching method that preserves the surface roughness, conductivity, and mobility of BaSnO$_3$ films.

These results demonstrate the tremendous potential of BaSnO$_3$ for the future of transparent electronics. The channel is 0.3 µm long and 0.93 µm wide. This is the first demonstration of a submicron scale BaSnO$_3$-based field effect transistor with complete depletion at room temperature. This result has been published in APL Materials January 2020. Two patent applications have been filed on the reactive ion etching of BaSnO$_3$.

References:

Figure 1, left: (a) The transfer characteristic of the TFT based on La-doped BaSnO$_3$ at $V_{DS} = 1$ V and the field-effect mobility. The peak field-effect mobility is 17.2 cm$^2$V$^{-1}$s$^{-1}$, and the on-off ratio is over $1.5 \times 10^8$. The subthreshold swing is 0.15 V dec$^{-1}$. (b) Transconductance of the device at $V_{DS} = 1$ V. The maximum transconductance is 30.5 mS/mm. (c) The output characteristic of the device at $V_{GS} = 2, 1, 0, -1, -2, -3, -4, -5, -6, -7$ V. The maximum drain current exceeds 0.467 mA/µm.

Figure 2, right: Drain current dependence on channel length ($L_{ch}$) when $V_{GS} = 2$ V and $V_{DS} = 5$ V. The drain current ($I_D$) is inversely proportional to the overall channel length except at the shortest channel length, showing little degradation with respect to device scaling. The deviation from linear behavior in the inset at the shortest channel length is likely due to the contact resistance and not short channel effects such as velocity saturation.