Decreasing Resistance of Aluminum based Single Electron Transistors as Quantum Charge Sensor

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Aluminum-based single electron transistors (SETs) can be significantly stabilized by introducing plasma oxidation techniques during fabrication and be applied as charge sensors for Silicon-Quantum Dots. Previous studies from ~20 years ago showed that the Aluminum-based SETs were too unstable to be integrated to quantum computing arrays as charge sensors due to their instability issue [1]. By fabricating the AlOx tunnel junction (TJ) thin film with the plasma oxidation technique, such instability can be essentially eliminated. However, the source-drain current of these Aluminum-SETs is typically at ~4 pA due to the high resistance of the AlOx tunnel junction. In the meanwhile, the commonly used Silicon-SETs have ~500 pA output to provide better signal-to-noise ratio and bandwidth. Therefore 4 pA output current is too small to provide a reliable readout signal at high frequencies. Therefore, our motivation is to decrease the resistance by lowering our oxidation duration and enlarging our tunnel junction area.

We have fabricated multiple batches of SET devices. When comparing our standard TJ device (100 nm · 46 nm per TJ) to enlarged TJ device (200 nm · 46 nm per TJ), we found that the enlarged TJ device has a significantly lower resistance, e.g., 68 MOhms compared to 260 MOhms. We have also fabricated two batches of the SET wafers under 3s and 7s oxidation duration. Among all 16 devices we measured on these two wafers, 12 of them are showing superconducting gap when measured under ~10 mK, and 8 of them are showing clear Coulomb blockade behavior. Resulting in a total 50% yield rate to the devices we made. We are still trying to get more data from both wafers and expect to present them during the conference.

[1] M. D. Stewart and N. M. Zimmerman, “Stability of Single Electron Devices: Charge offset drift,” *Applied Sciences*, vol. 6, no. 7, pp. 187, June. 2016

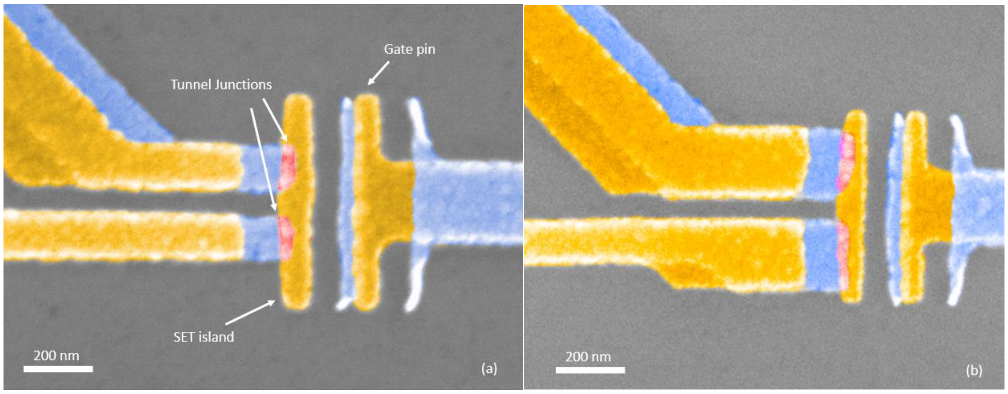

Fig. 1 SEM photos for (a) standard TJ SET, and (b) enlarged TJ SET, the TJ areas are enlarged by double the width of source/drain pins.

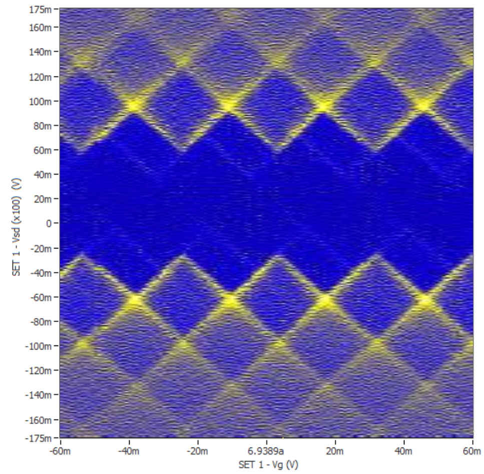

Fig. 2 – Coulomb diamond diagrams from a 7s-oxidized transverse SET, showing a good blockade behavior.

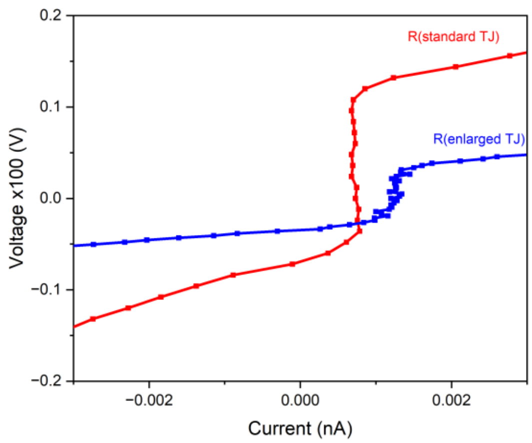

Fig. 3 – Isd-Vsd curves comparison between an enlarged TJ device and a standard TJ device, it is clear that the enlarged device has lower I-V slope.