New method of fabrication of suspended metallic Single Electron Transistor (SET)

M. I. Rahaman, G. P. Szakmany, A. O. Orlov, and G. L. Snider
Electrical Engineering Dept, University of Notre Dame, Notre Dame, IN 46556
mrahaman@nd.edu

Because of their high charge sensitivity, Single Electron Transistors (SETs) have been of research interest for the past few decades. Unfortunately, this unsurpassed charge sensitivity is also the nemesis of the SETs - as any kind of random charge offset near the device will move it from its desired bias point. The main sources of these random offset charges are the stochastic occupation of charge traps in the dielectric tunnel barriers of SET and the substrate upon which the SETs have been fabricated.

Previous research to eliminate the substrate offset charge noise has investigated in stacked[1] and suspended SETs[3]. For suspended SETs, the SETs were first made on a SiNx[2] or polymer[3] sacrificial layer on a silicon substrate and as final step the SiNx or polymer was etched or ashed to suspend the SET island a relatively small distance of 300nm and 50nm respectively above the substrate. Charging energy is one of the critical performance parameters of SET which determines the highest operating temperature of the SETs. The charging energy of these previous SETs [1,2,3] was very low, and the gate-dependent charging characteristics of the SETs was not reported in any of the aforementioned works[1,2,3].

Our suspended SETs, Fig. 1, are suspended in a procedure different from reported works[1,2,3]. The Aluminum SET was first fabricated on a highly resistive silicon substrate (>2 kΩcm) by a standard dual-angle shadow evaporation process[4]. The SET was then suspended by selective static etching of the silicon substrate under the island of the SET by XeF_2. This removes any substrate materials within 2-3μm of the island. The charging energy of our suspended SETs were ~ 2meV, significantly larger than the reported works[1,2,3]. The gate-dependent charging characteristics of the SETs were found by sweeping the gate voltage (V_g) from 0 to 1V twice at 2.4K which showed Coulomb Blockage Oscillations (CBO), Fig. 2, for both suspended SET and SET on silicon substrate. The suspended SET showed lesser shift in their CBOs compared to the SET on silicon substrate which are shown in Fig. 2. Since the substrate under the SET has been removed, these devices are expected to show low stationary 1/f noise. Lastly, due to its unique mechanical structure, this device can operate as Nano MEMS and should enable a study of interactions between charge transport and mechanical effects such as oscillations and strain.

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[3] T. Li *et al., Applied Physics Letters, 91*(3), 033107, 2007.
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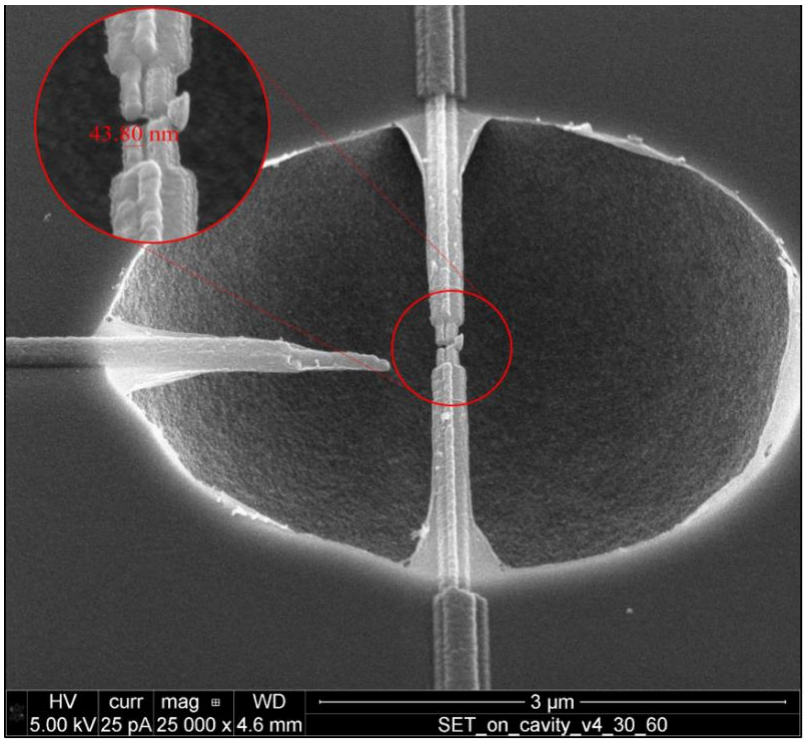

Fig 1: SEM image of suspended Aluminum SET. The gate is hanging on the cavity from the left hand side. The top and bottom electrodes can be used as source or the drain of the SET. There is Aluminum Island between source and the drain which is separated by two Al_2O_3 tunnel barriers. All the electrodes are made of Aluminum. Inset contains the magnified SEM image of the SET.

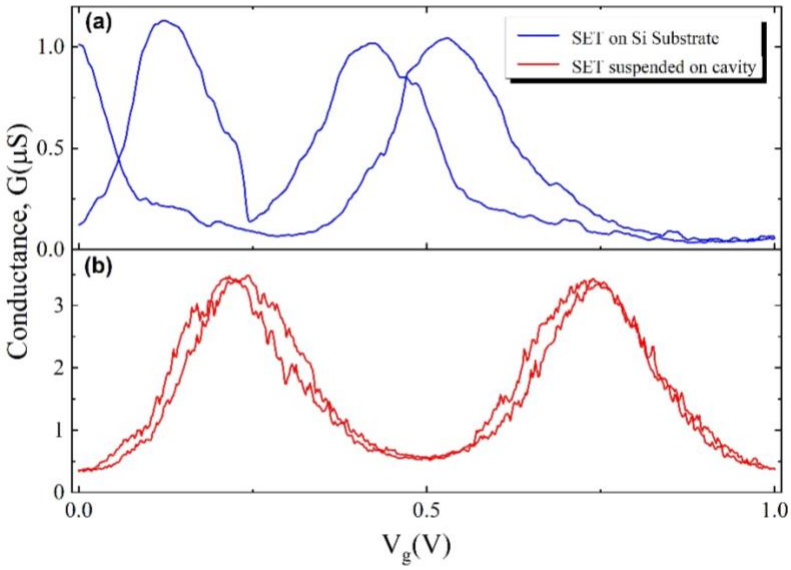

Fig 2: Gate-dependent charging characteristics of the SETs, dI_{ds}/dV_{ds}-V_g, measured at V_{ds}=0Mv at 2.4K. V_g was swept twice form 0 to 1V for each SET. SET on the silicon substrate (a) shows larger shift in their conductance oscillation with respect to gate voltage (V_g) compared to the SET suspended on the SET (b).