Nanometric Tips for 2D Materials Quantum Dots

Adi TIHIC[1,2], Dipti UMED SINGH[1,2], François FILLION-GOURDEAU[3,4], Pierre LEVESQUE[3], Steve MacLEAN[3], Paul G. CHARETTE[1,2], Dominique DROUIN[1,2], Serge ECOFFEY[1,2]

1. Institut Interdisciplinaire d'Innovation Technologique (3IT), Université de Sherbrooke, 3000 Boulevard de l'Université, Sherbrooke, J1K OA5 Québec, CANADA
2. Laboratoire Nanotechnologies Nanosystèmes (LN2) - IRL3463, CNRS, Université de Sherbrooke, Sherbrooke, J1K 0A5 Québec, CANADA
3. Infinite Potential Laboratories, Waterloo, Ontario, Canada, N2L 0A9
4. INRS-Énergie, Matériaux et Télécommunications, Varennes, Québec, Canada J3X 1S2

adi.tihic@usherbrooke.ca

Following the discovery of graphene, gated two-dimensional materials (2DMATs), have emerged as a key research area. Applying specifically designed electric field to these materials enable the formation of quantum dots (QD), paving the way for applications in quantum, electronic and optical technologies [1]. It has been shown that the polarization of a scanning tunneling microscope (STM) tip permits the creation of QD in graphene or other 2DMAT like transitional metal dichalcogenides (TMD) [2]. Inspired by STM principles, our approach aims to integrate electrically addressable nanometric tips within the device architecture, targeting an apex 1-3 nanometers away from the target 2DMAT for QDs formation [3] as shown on Fig. 1.

Fig. 2 shows a simplified schematic process flow of the embedded Si tips: 50-150 nm resist dots are patterned with E-Beam lithography using ARN7520 new resist on heavily n-doped Si wafer; tips shaping is done with plasma etching in two steps, isotropic followed by anisotropic etching using fluorine based chemistry; further sharpening of the tips is done by a 10 nm thermal oxidation at 1000 °C followed by HF etching; 400 nm of SiN is deposited by LPCVD at 785 °C; and finally the sample is planarized with CMP using an alkaline 50 nm silica slurry solution. Fig. 3 shows etched Si tips prior to the SiN deposition, while Fig. 4 is a top-view SEM image of embedded Si tips after CMP with the tip apex very close to the surface.

The fabricated tips feature an apex diameter of ~10 nm, adjustable height of 150-500 nm, and an apex-to-surface spacing of 1-10 nm. Theses dimensions align with our device simulation for QDs formation, which will be detailed in the publication. 2D materials have been transferred on top of these precisely engineered systems and are now ready for QD characterization, using STM spectroscopy or time resolved photoemission electron microscopy (TR-PEEM).

1. James Singh, Konthoujam et al. Nanomaterials 11,6 1549
2. E A Quezada-López, et al. 2020 Nanomaterials 10 1154A
3. S A Guerrera and A I Akinwande 2016 Nanotechnology 27 29530

Figure 1 Schematic representation of a 2DMAT-Tip system

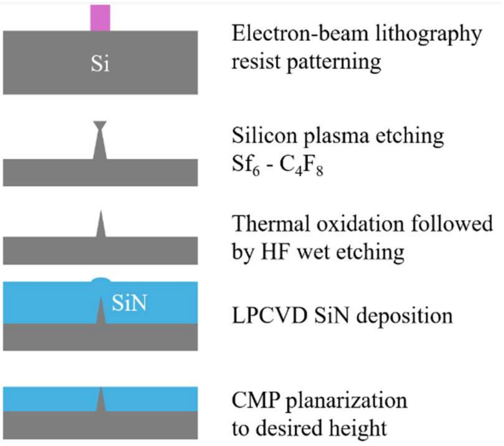

Figure 2 Schematic representation of the embedded Si tip process flow

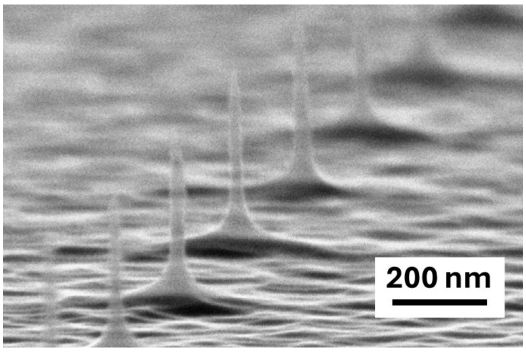

Figure 3 SEM image, sharpened tips after Si oxidation and HF etching.

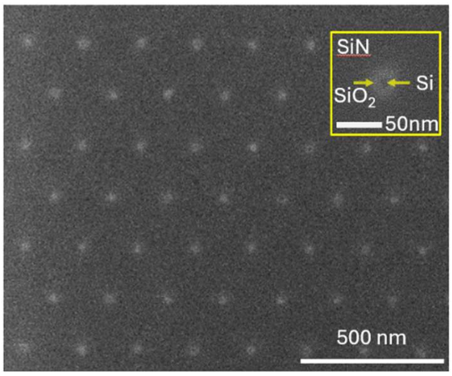

Figure 4 Top-view SEM image of a planarized matrix of embedded tips. The yellow zoom insert shows the Si tip’s apex layered by SiO_2 and SiN