NanoFrazor – A Versatile Nanopatterning Tool for 2D materials

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NanoFrazor (thermal scanning probe) lithography has recently entered the market as the first true alternative to electron beam lithography (EBL) [1]. It uses a heatable tip that can pattern and simultaneously inspect nanostructures. NanoFrazor can pattern very high-resolution (< 10 nm half-pitch) nanostructures by locally evaporating resist materials. The structures are inspected by the cold tip before or during with the patterning, enabling stitching and markerless overlay with sub-5 nm accuracy [2]. This technique is compatible with all standard pattern transfer processes [3,4].

To study the properties of 2D materials, one often needs to shape them (e.g. into nanoribbons, Hall bars etc), to contact them or to modify them mechanically or chemically. Predominant fabrication process (EBL followed by etching or lift-off of metal) has a limited resolution due to proximity effects; it may require complex overlay procedures; and it often yields poor quality non-ohmic contacts [6]. We show that NanoFrazor lithography can be used to shape the flakes with high precision (Figure 1a-b) [7-8]; to make high-quality contacts on 2D materials (Figure 1c) [5]; to induce precisely controlled local strain (Figures 1d-e) [9]; and to locally define the doping through absorption of charged defects from controlled environment (Figure 1f) [10]. NanoFrazor also has an integrated direct laser sublimation module for rapid patterning of coarse features, e.g. contact pads [11].

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FIGURES

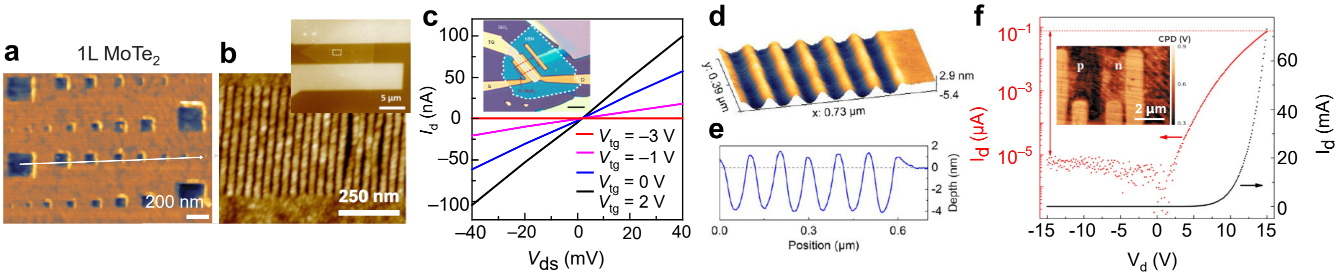

Figure 1: Versatile devices fabricated using t-SPL (a) AFM topography of nanosquare arrays in 1L MoTe$_2$ obtained by thermomechanical nanocutting. Feature sizes in the range from 20 to 200 nm along the line [8]. **(b)** AFM image of 18-nm half-pitch 1L MoS$_2$ nanoribbon array patterned by t-SPL and reactive ion etching. Inset shows the position and orientation of the nanoribbons array [7]. **(c)** Small-voltage I_d (V_{ds}) curves at different top-gate voltages show ohmic behaviour of the contacts patterned by t-SPL. Inset: Optical image of the 1L MoS$_2$ FET fabricated on the h-BN dielectric, for which the IV curves are shown. Scale bar 5 µm [5]. **(d)** Three-dimensional AFM topography of nanoripples written into 1L MoS$_2$ and **(e)** Depth profile of the nanoripples. The nanoindentation depth is around 4 nm and the pileup height is around 1.5 nm. Strain up to 10 % resulting in tuning the bandgap to 180 meV was obtained [9] **(f)** Output curve of a lateral p–n junction in logarithmic (red) and linear scale (black), measured at the optimal back gating of −32 V. A rectification ratio >10^4 has been achieved. Inset: a KPFM image of a FET channel after the formation of the lateral p–n junction. p-n junction defined by localized dopant absorption via thermochemical SPL [10].