Tip-Based Fabrication of Single-Layer MoS_2 Nanoribbon Transistors with 30-nm Channel Width

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This paper reports the fabrication of single-layer MoS_2 nanoribbon field-effect transistors (FET) using tip-based nanofabrication. The tip deposits polymer structures to mask the device layer of MoS_2, as well as the metal contacts, during etching. Figure 1 shows a fabricated device.

The fabrication starts chemical vapor deposition grown MoS_2 monolayers transferred onto 285 nm thick SiO_2 on a substrate of p-doped Si. Next, metal electrodes (5 nm Ni/30 nm Au) are deposited on the MoS_2. A heated atomic force microscope cantilever tip defines the channel by depositing Poly(methyl methacrylate) (PMMA) nanoribbons onto the MoS_2 monolayers between the electrodes[1]. Etching gas XeF_2 removes the unmasked MoS_2. The tip also deposits 3 μm wide polymer structures to protect the metal contacts. Finally, 10 nm thick Al_2O_3 deposited using atomic layer deposition passivates the device.[2]

Figure 2 shows example device data. We fabricated and tested eight back-gated monolayer MoS_2 FETs. The results for a 30 nm wide nanoribbon device are as follows. After nanoribbon patterning and ALD passivation, the current on/off ratio was about 10^4, and the device field-effect mobility was 8.53 cm^2/ Vs.

We present here a novel method to fabricate 2D nanoribbon transistors, by combining conventional optical lithography with tip-based nanofabrication. To the best of our knowledge, this paper is the first published report of monolayer MoS_2 nanoribbon transistors.

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[1] W. K. Lee, J. T. Robinson, D. Gunlycke, R. R. Stine, C. R. Tamanaha, W. P. King, and P. E. Sheehan, Nano letters **11** (12), 5461-5464 (2011).
[2] S. Y. Kim, S. Park, and W. Choi, Applied Physics Letters, **109** (15), 152101 (2016).

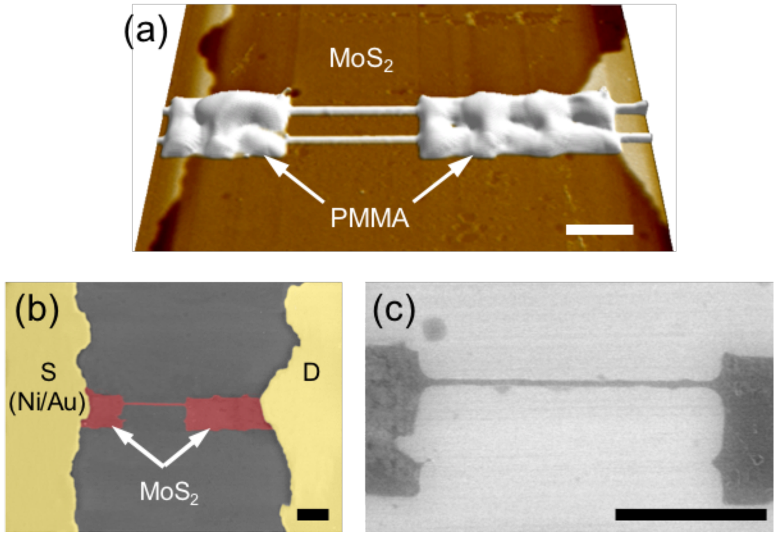

Figure 1: (a) AFM topology of PMMA mask on a MoS_2 device after thermal dip-pen nanolithography (tDPN). (b) False-colored SEM image of a monolayer MoS_2 nanoribbon device. (c) Magnified SEM image of a 36-nm-wide MoS_2 nanoribbon shown in (b). The scale bars in (a)-(c) are 1 μm.

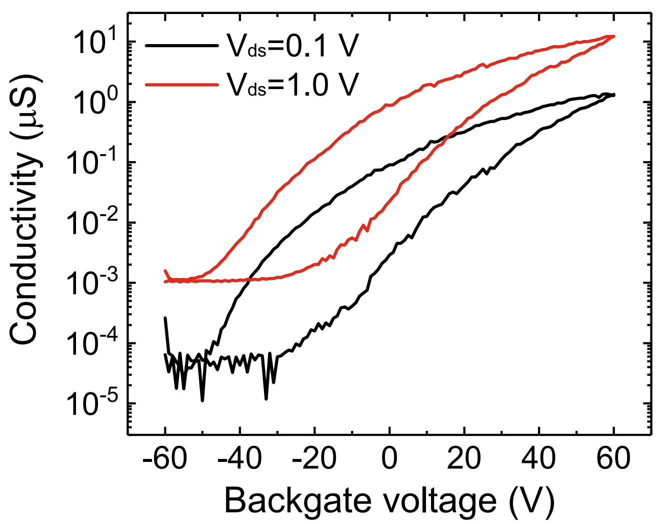

Figure 2: Transfer curve for a 30 nm wide nanoribbon device after nanoribbon patterning and ALD passivation. The current on/off ratio was about 10^4, and the device field-effect mobility was 8.53 cm^2/ Vs.