Transfer on large diameter cavity substrate: Characterization of 2D materials membranes

Trousset Pierre
Brunet Paul, Alava Thomas, Le Van-Jodin Lucie
Univ. Grenoble Alpes, CEA, Leti, F-38000 Grenoble, France,
lucie.levan-jodin@cea.fr

The large scale transfer of 2D materials on different substrate is one of the most important challenge to use 2D materials inside electronic devices. The creation of 2D materials membranes enables to reveal new properties for electronic, biosensors or quantum technologies[1]. By taking advantage of the film suspension, we can easily determine its mechanical properties thanks to classic characterization tools[2, 3]. Moreover, the 2D NEMS manufacturing enables to explore more exotic properties of 2D Transition Metal Dichalcogenides (TMD) as solid-solid metal to insulator transition[4]. Based on this context, we set up a similar membrane characterization using AFM as the one described here [2] enabling to obtain the Young modulus of the MoS_2 film. By transferring 2D film on a substrate with cavities and venting to evacuate the water used during the transfer, we achieved to obtain a suspended MoS_2 membrane with a diameter of 13 µm. In accordance with the literature, we observed that larger and shallower is the cavity, harder is to obtain a membrane [5]. Moreover, we have observed that circular and hexagonal cavities are more adapted to suspend a 2D film above compared to square cavities. Indeed, as it can be seen in (Figure 1), successfully suspending a membrane depends on the shape, the aspect ratio of the cavity but also the presence of venting. To corroborate these observations, a numeric tool, which use SEM and optical microscopy images, will be developed to easily determine the yield of suspended membranes obtained for every cavity size and shape.

References

[1] T. Yildirim *et al.*, « Towards future physics and applications *via* two-dimensional material NEMS resonators », *Nanoscale*, vol. 12, n° 44, p. 22366-22385, 2020, doi: 10.1039/D0NR06773C.
[2] A. Castellanos-Gomez, M. Poot, G. A. Steele, H. S. J. van der Zant, N. Agraït, et G. Rubio-Bollinger, « Elastic Properties of Freely Suspended MoS2 Nanosheets », *Advanced Materials*, vol. 24, n° 6, p. 772-775, 2012, doi: 10.1002/adma.201103965.
[3] G. Cao et F. An, « Mechanical properties characterization of 2D materials via pressure bulge testing », *J. Phys. D: Appl. Phys.*, vol. 56, n° 7, p. 075302, janv. 2023, doi: 10.1088/1361-6463/acadeb.
[4] S. Song, D. H. Keum, S. Cho, D. Perello, Y. Kim, et Y. H. Lee, « Room Temperature Semiconductor–Metal Transition of MoTe $_2$ Thin Films Engineered by Strain », *Nano Lett.*, vol. 16, n° 1, p. 188-193, janv. 2016, doi: 10.1021/acs.nanolett.5b03481.
[5] J. W. Suk *et al.*, « Transfer of CVD-Grown Monolayer Graphene onto Arbitrary Substrates », *ACS Nano*, vol. 5, n° 9, p. 6916-6924, sept. 2011, doi: 10.1021/nn201207c.

Figures

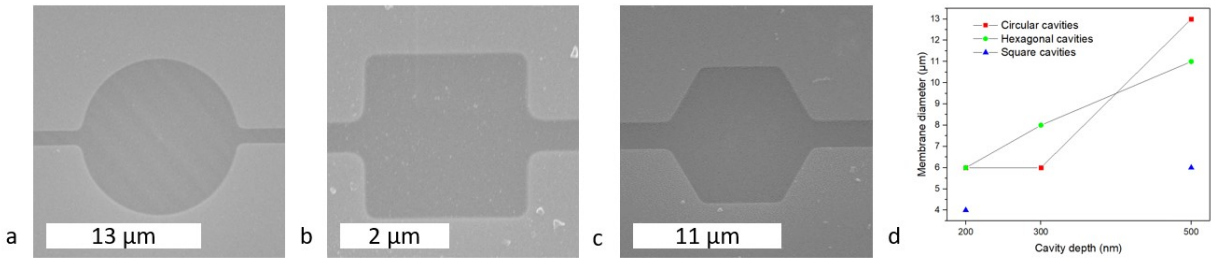

Figure 1: a, b, c: SEM images of suspended MoS_2 above circular, square and hexagonal cavities respectively. d: Largest obtained membrane in function of the cavity depth for each experimented shape.