GRAPHENE AND 2DM VIRTUAL CONFERENCE & EXPO

10 ANNIVERSARY

Graphene online 2020 October 19-23

Study of large-scale 2D transfer using the spalling process

J. David-vifflantzeff[a], K. Sharma[b], H. Okuno[b], S. Cadot[a], L. Le Van Jodin[a]

[a]Univ. Grenoble-Alpes, CEA, LETI, *38000 Grenoble, France* / [b]Univ. Grenoble-Alpes, CEA, IRIG, *38000 Grenoble, France*

Introduction

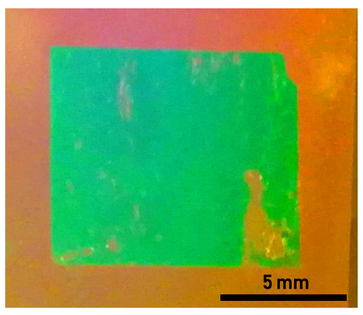
With the very active research in the 2D field lately, a wide variety of 2D materials on different growth substrate are obtainable. However, in most cases, a transfer toward another substrate is needed to have a functional device.

Here we present a method of transfer which works on almost every 2D/substrate combinations: the Spalling. This process is particularly interesting for 2D material which are very difficult to delaminate with the common wet polymer transfer.

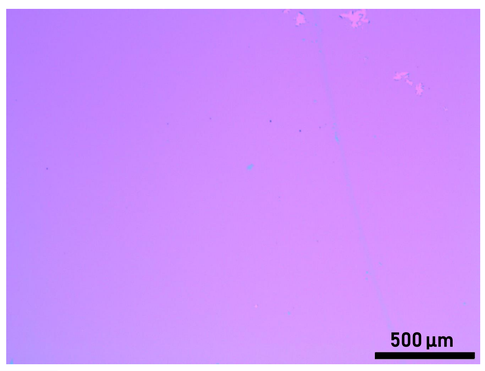
Transfers results

We studied our spalling transfer with two 2D materials : MoS_2 3 to 6 layers grown on SiO_2 by the SDEP lab from CEA, LETI. And Graphene monolayer grown on sapphire by the Aixtron company.

With our process we succeed in transferring above 1 cm^2 of continuous layer of this two materials onto SiO_2 wafer. The wet transfer of MoS_2 is relatively easy and well-know and will serve as a reference to benchmark the spalling method. Whereas the spalling of graphene on sapphire is more interesting as there isn't a reliable method to transfer it yet.



Optical image of MoS_2 3ML after spalling on SiO_2.



Optical image of graphene monolayer after spalling on SiO_2.

Delamination energy

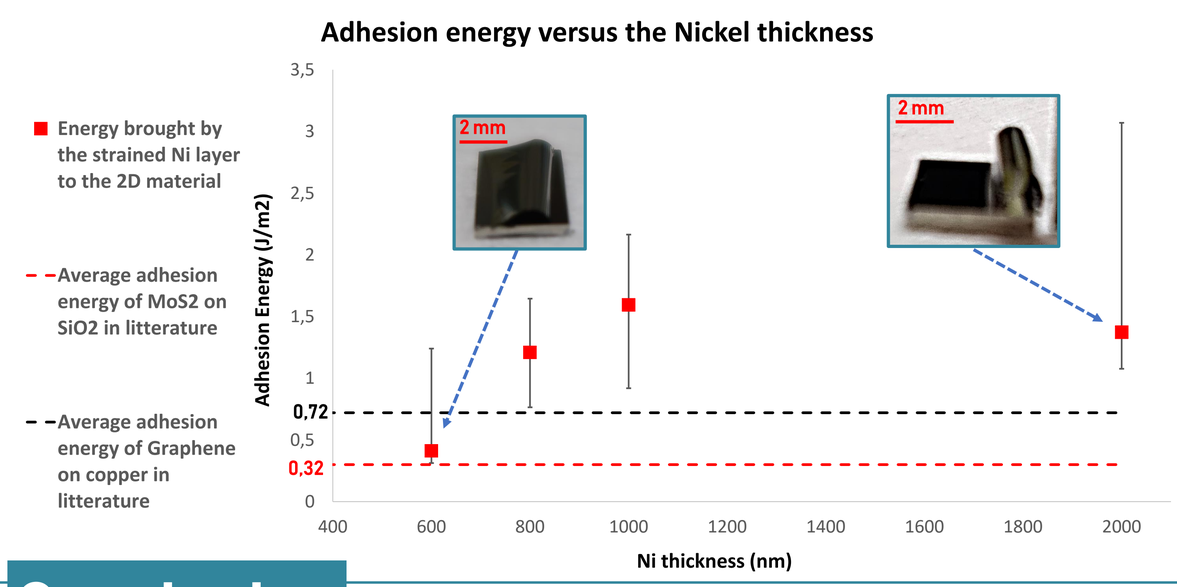
The purpose of the strained metal layer deposited on the 2D material is to help with the delamination. The amount of energy this strained layer bring to the 2D can be calculated by the formulae of Shim et al:

$$\Gamma_{\text{film-substrate}} = \frac{(1-\nu)H\sigma^2}{2Y}$$

Formulae proposed by Shim et al[1]

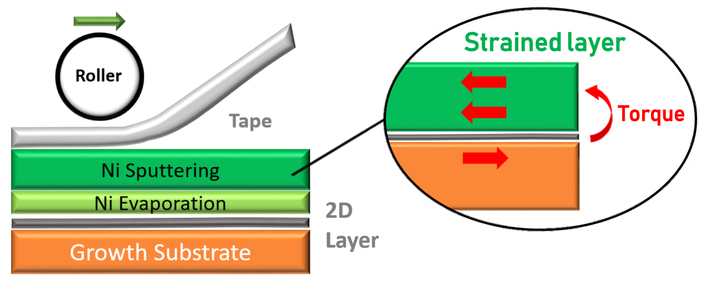
Γ is the energy by surface, ν, H, σ and Y are respectively the Poisson factor, the thickness, the strain and the Young modulus of the metal layer.

By increasing the thickness of the Ni layer until a spontaneous delamination is observed, we can deduce the adhesion energy 2D / substrate. No sample delaminated for the graphene, so $\Gamma > 1{,}5$ J/m², while every samples delaminated for MoS_2, inducing : $\Gamma < 0{,}4$ J/m²

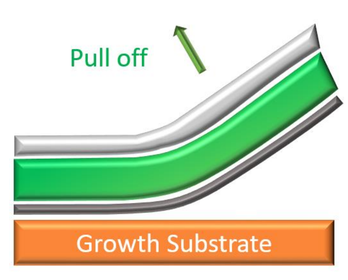


Spalling process

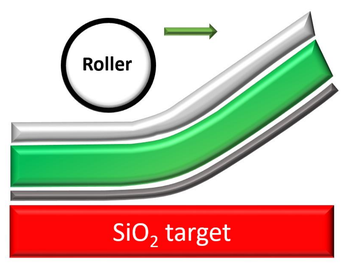
1) Metal deposition and tape set-up



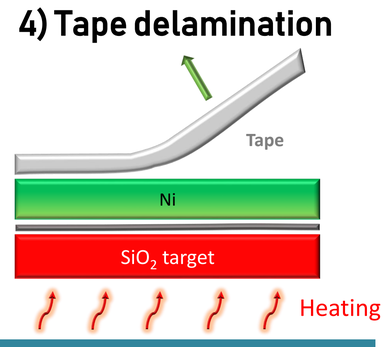
2) Peeling



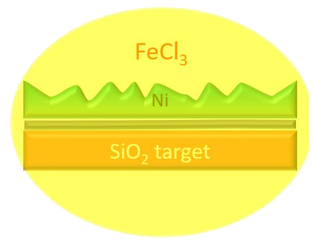
3) Report on target



4) Tape delamination

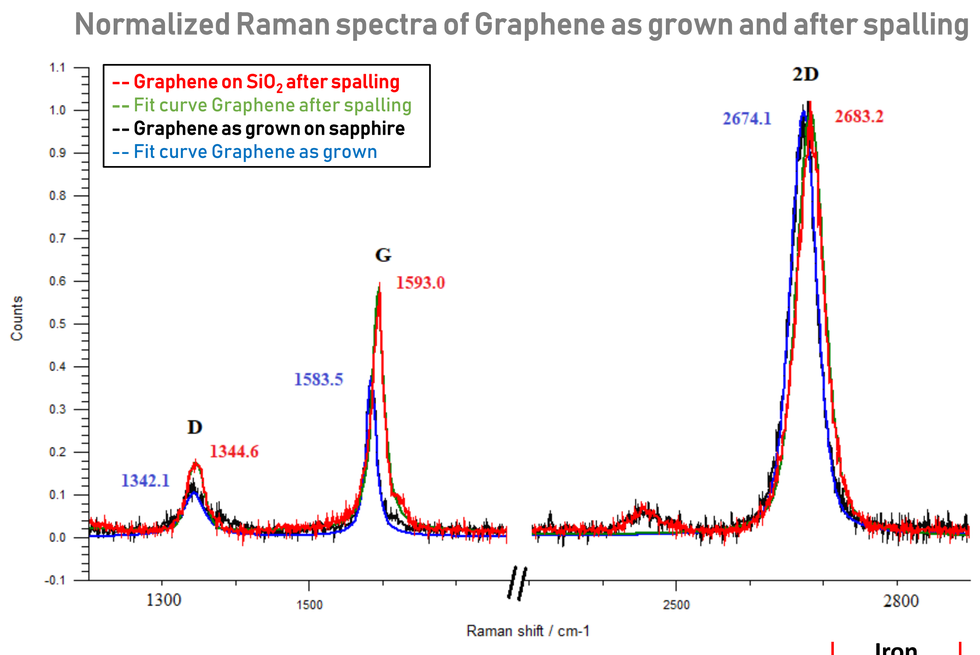


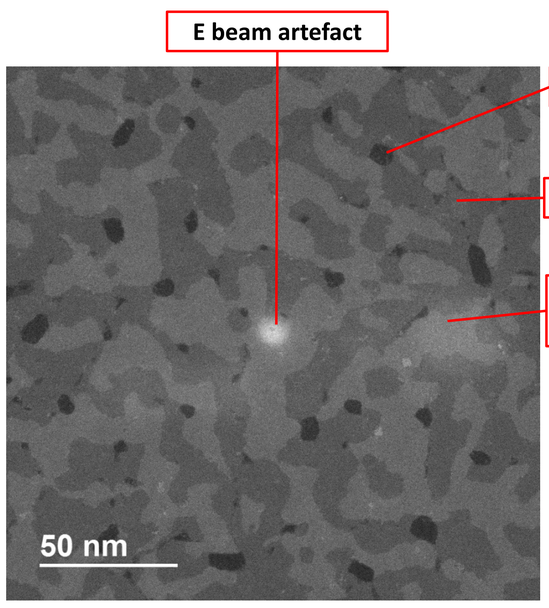
5) Nickel etching



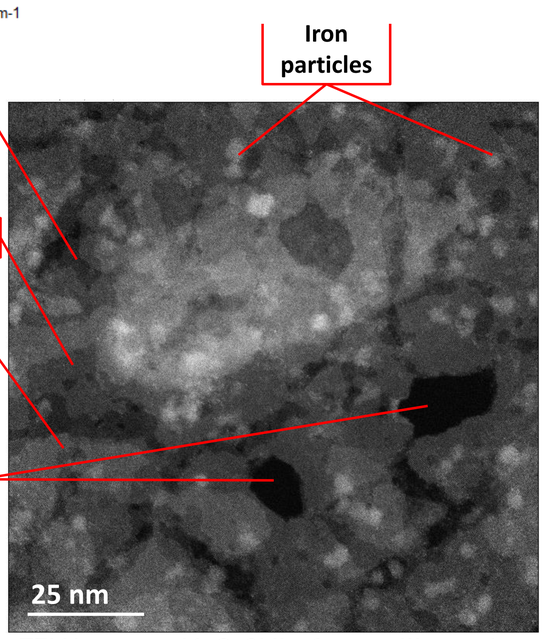
Defects and Contamination

In order to investigate the contamination brought by the palling transfer, we made Raman and TEM analysis. With TEM we compared pristine MoS_2 and spalled MoS_2, both 3 layers thick. The report on the grids was done with the common wet process.





TEM image on MoS_2 3ML after wet transfer.



TEM image on MoS_2 3ML after spalling and wet transfer

Conclusion

The spalling process enable the transfer of different 2D materials on the centimeter scale with the same protocol. Including 2D materials strongly bonded to their growth substrate, or for whom it doesn't exist a reliable delamination method yet, like graphene on sapphire. Moreover, the spalling shouldn't damaged the growth substrate, which could be re-used afterwards. However we detect some metallic contamination on the 2D materials after transfer. So more investigation is needed one the cleaning part after the etching of Nickel.

CONTACT PERSON

julien.david-vifflantzeff@cea.fr

lucie.levan-jodin@cea.fr

REFERENCES

1 Shim, J. *et al*, *Science 2018, vol* 362, pp. 665–670
2 Backes, C. *et al. 2D Materials 2020*, vol **7**

ACKNOWLEDGEMENT

We thanks the company Aixtron for providing the Graphene on Sapphire.

Graphene online 2020