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## Wet jet mil exfoliation: High-quality 2D crystals at the fingertips for industrial applications.

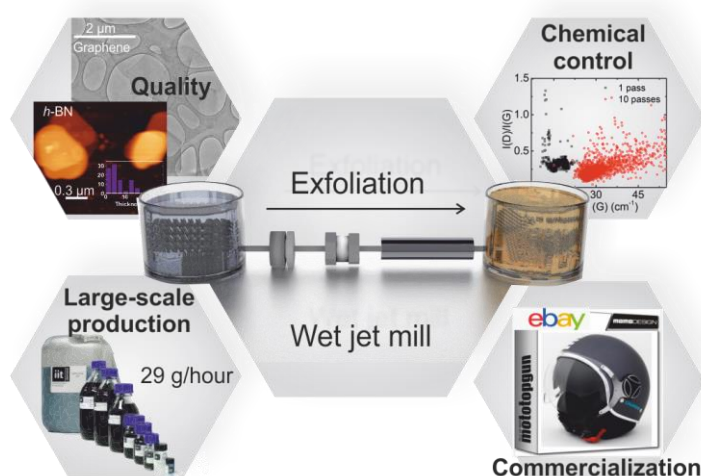
The production of two-dimensional (2D) crystals is facing serious issue linked with the exploitation of such materials at the industrial level[1]. However, the practical realization of any commercial application requires efficient synthesis methods[2]. Although many production techniques have been developed,[2] the most promising approach for large-scale production of 2D crystals is the liquid-phase exfoliation (LPE) of their bulk counterparts[3]. However, the main limitations of LPE are the low production rate (g/h) of 2D crystals, and no control in the flakes sizes during the exfoliation processing. In fact, by exploiting ultrasonication[3], it is possible to get an average production rate of 1 g/h, with sizes ranging from tens of nm to few microns[3,4].

To tackle the aforementioned limitations, here we present the latest results on the LPE of bulk-layered crystals. The process is founded on high-shear wet jet milling (WJM, Fig. 1). This technique allows us to have a production rate of ~24 g/h. The developed WJM process has been applied to a large variety of layered crystals ranging from graphite to hexagonal boron nitride, transition metal dichalcogenides, and black phosphorus. The obtained 2D crystals have been employed for several applications, ranging from energy devices (storage and generation) to polymer composites.

### References

- [1] A. Ferrari, et al., *Nanoscale*, 7 (2015) 4598.
- [2] F. Bonaccorso, et al., *Mater. Today*, 15 (2012) 564.
- [3] A. E. Del Rio, et al., *Mater. Horizon*, 5 (2018) 890.
- [4] A. E. Del Rio, et al., Patent No. WO2017089987A1 (2015).

### Figures



**Figure 1:** Central hexagon, schematic of the wet-jet mill. Top-left, AFM of BN flakes and TEM of graphene. Top-right: Analysis Raman on the defect type. Bottom-left, 20L of graphene dispersion synthesized in 8.5 hours. Bottom-right, a commercially available application of the crystals exfoliated using the WJM.

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