Beyond graphene: how to synthesize hexagonal boron nitride crystals by chemical route

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Hexagonal boron nitride (hBN) occupies a special place in the vast world of two-dimensional (2D) materials due to its excellent thermal, chemical, mechanical, and dielectric properties. Whether used as a substrate or as an active layer, high-quality 2D hBN holds great promise for future research applications, especially for optoelectronic devices. However, it is now well established that the optical, electronic, and transport properties of these systems are highly dependent on the chemical purity and crystallinity of the hBN used, which in turn are highly dependent on the synthesis approach chosen. Vapor-phase processes, like chemical vapor deposition, can achieve large-scale coverage, but self-standing hBN crystals provide exfoliated nanosheets (BNNS) of unmatched purity and crystal quality which are still preferred for demanding applications.

In order to obtain high-quality, large-sized BNNSs, we propose a synthesis route based on the polymer-derived ceramics (PDCs) process [1]. PDCs consists of synthesizing a molecular precursor and then polycondensing it into an inorganic polymer that can be shaped before ceramization. This chemical route allows the elaboration of ceramics with adapted textural and structural properties, presenting specific shapes that cannot be easily obtained by conventional powder technology. By coupling PDCs to a sintering step, single crystals of hBN of a few millimeters were successfully obtained from a borazine precursor at a relatively low temperature [2]. The hBN obtained by this method shows a very high crystal quality attested by a Raman FWHM value of 7.6 cm^{-1}, one of the best reported in the literature [3]. BNNSs exfoliated from these crystals have been used to fabricate metal-hBN-metal capacitor devices to measure the dielectric constant and the breakdown electric field of hBN, which were found to be 3.136 and 0.64 $V.nm^{-1}$ respectively [4], i.e very close to the theoretical values. Such functional measurements allow the assessment of the overall crystal quality. These BNNSs have also been used to encapsulate Transition Metal Dichalcogenides (TMDs) tested by optical spectroscopy. The photoluminescence widths of WSe_2 and $MoSe_2$ neutral exciton lines at 4K were measured within the 2-3 meV range [3] which is comparable to the results obtained with the highest quality hBN. All these results demonstrate that these BNNSs are relevant for future electronic and optoelectronic applications.

References

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