2D Amorphous Materials and their Applications

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Bulk amorphous materials have been studied extensively and are widely used in industry, yet their detailed atomic arrangement is unknown. Unlike bulk materials, the structure of 2D or monolayer amorphous carbon (MAC) can be determined by atomic-resolution imaging [1]. Recently we have shown that such a structure can indeed be synthesised as free-standing membrane and is topologically different from its crystalline counterpart. Interest in atomically thin amorphous materials has recently surged, because they exhibit properties not observed in their crystalline counterparts. From an application point of view, they have the potential to address bottlenecks in both quantum device fabrication and industry. I will give three examples.

First, I will discuss the low temperature synthesis, by laser-assisted chemical vapour deposition of free-standing monolayer amorphous carbon/amorphous graphene. Extensive characterization by transmission electron microscopy reveals the complete absence of long-range periodicity and a threefold-coordinated structure with a wide distribution of bond lengths, bond angles, and five-, six-, seven- and eight-member rings. Electronic characterization of free-standing MAC shows that it is insulating, with resistivity values comparable to boron nitride grown by chemical vapour deposition. Also, it is surprisingly stable and deforms to a high breaking strength, without crack propagation from the point of fracture. I will discuss its potential use both as a multifunctional barrier film for applications such as magnetic media and interconnects. Next, I will discuss how such a 2D film can be synthesised as nanoporous monolithic amorphous carbon foam using Spark Plasma Sintering (SPS). I will discuss its potential for applications, e.g., as supercapacitors. Il will conclude my talk by discussing the use of amorphous BN as an atomic sieve for dilute magnetic doping of 2D materials. I will demonstrate its potential for creating ferromagnetic superconductors through an usual RKKY coupling within the superconducting gap.

[1] Toh, C.-T. et al. Synthesis and properties of free-standing monolayer amorphous carbon. Nature 577, 199–203 (2020).