2D Materials Growth: Prospects and Challenges

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The isolation of graphene[1] now almost a decade ago has given rise to the revitalization of an old full set of materials, two-dimensional materials (2DM), that have exceptional electrical, chemical and physical properties. Some of the materials under investigation in addition to graphene are hexagonal boron nitride (h-BN), semiconducting, metallic, and superconducting, transition metal dichalcogenides (TMD) with a general chemical formula, MX_2 where M is for example equal to Mo, W, Ta, Nb, Zr, Ti, and X = S, Se and Te, and others. While h-BN is an excellent 2D insulator, TMD materials provide what neither graphene nor h-BN can, bandgap engineering that, in principle, can be used to create devices that cannot be fabricated with h-BN and graphene. Therefore, there is hope to integrate these materials for numerous device types for many applications ranging from inkjet printing, photonic applications, flexible electronics, and high performance electronics. However, before the engineering community can develop these products that use 2DM, basic material properties for each application needs full definition so as to select the most appropriate techniques for material preparation and growth.

A number of deposition techniques have been used to prepare large area graphene, growth on SiC through the evaporation of Si at high temperatures[2], precipitation of carbon from metals[3], and chemical vapor deposition on Cu[4]. Direct growth of good quality graphene on dielectrics/semiconductors other than SiC has only been reported recently on Ge[5], but not on others. Considering that before 2004 only small flakes of isolated graphene could be grown, the community has made significant progress on large area continuous graphene films on Cu and Ge[6]. In addition, there are numerous chemical exfoliating techniques used to form graphene with a range of sizes[7]. CVD graphene and graphene on SiC have been shown exceptional transport properties, equivalent to the best graphene exfoliated from mined graphite. Thin film growth of h-BN on the other hand has been found to be more difficult than graphene nevertheless there are many reports on large area growth on metals but the quality is still not equivalent to h-BN exfoliated from "bulk grown h-BN" when used as a substrate or as a gate dielectric for graphene devices.

Transition metal dichalcogenides present altogether different opportunities and difficulties in the preparation of low defect density large area single crystals. Of the many TMDs to select from, a lot of attention has been dedicated to MoS_2 because of its long history in rheological applications and availability of naturally occurring crystals and at this time it is used as a platform for materials growth development techniques. Vapor transport, chemical vapor deposition, and molecular beam epitaxy are being developed to produce these materials for initial studies of materials physics device fabrication[8,9].

In this presentation I will present the state of the art results of graphene, h-BN, and a few TMD materials and their prospects for future electronic device applications.

References

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