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2D ENGINE: Engineering of new 2D materials phases not existing in Nature

Since the discovery of graphene in 2004 and the development of other 2-dimensional (2D) materials that followed, they have promised to be excellent materials for a wide range of applications, such as (opto)electronics, new field-effect transistors, biosensors, catalysts, solar cells, drug delivery, and tissue engineering. Up to now, however, a major impact on society through industrial applications is missing, due to the lack of recipes to produce these materials fast, reproducibly, and with high quality. The current preparation method is chemical vapor deposition, in which precursors react at a catalyst surface to form the desired 2D material. However, the quality of materials grown in this manner is often insufficient for industrial applications. This is mainly due to the simultaneous reaction of many precursor molecules at the catalyst, from which multiple flakes grow. When these flakes merge to form a larger sheet of 2D material, grain boundaries remain, that significantly decrease the unique properties of the material. In addition, the material takes over the grain boundaries that are present on the catalyst on which it grows.

Recently, we have shown that if graphene is grown on liquid instead of solid copper, its quality significantly improves. There are two main reasons for this: 1) liquid copper itself has no grain boundaries that will be implemented in the growing graphene; 2) on liquid copper, graphene flakes are able to freely rotate and therefore can "stitch" perfectly Additionally, the growth speed is much higher, which becomes relevant for an industrial process.

Unfortunately, graphene is not suitable for active transistor devices since the device cannot be turned off as required for digital circuit applications. Also, the lack of an energy gap in graphene inhibits its use as an active light emitter source which would have been otherwise ideal for integrated photonic devices enabling on-chip waveguide communications. Therefore, in this project we aim to investigate and characterize the growth of a new class of 2D materials, that do not exist in Nature, but can only be prepared in the lab. We will target the growth of AlN, GaN, ZnO, SiC, and BN on liquid metal catalysts. These materials will, unlike graphene, have a bandgap that makes them suitable for digital nano-and opto-electronics. It is also expected that the new materials will be more stable and process compatible with Si compared to currently available solutions. Using the new phases, our long-term ambition is to enable (a) ultimate downscaling of nanoelectronic devices, (b) optimal integration of light source-waveguide assemblies for on-chip communications, and (c) introduce new functionalities.