

# Observing while it happens: CVD growth of graphene inside a scanning electron microscope

Zhu-Jun Wang<sup>1</sup>

<sup>1</sup>. School of Physical Science and Technology, ShanghaiTech University, Shanghai, China.

In my presentation, I will elucidate the capabilities of environmental scanning electron microscopy (SEM) and champion its use as an invaluable in-situ surface science instrument. Following a showcase of illustrative examples centered on gas-phase reactions on metallic substrates, I will direct attention to the chemical vapor deposition (CVD) synthesis of graphene. Through this lens, I aim to emphasize how direct observational techniques have afforded critical understanding into the growth dynamics and etching characteristics of both mono-layered and multi-layered graphene.

Drawing from direct observational data, we have recently postulated a plausible mechanism for the assisted self-assembly of twisted layer graphene, as illustrated in Fig.1. This procedure, seamlessly integrable into conventional chemical vapor deposition (CVD) growth, can be aptly analogized to the artful practices of Origami and Kirigami with paper. The process encompasses the deliberate induction of wrinkle formation in monolayer graphene, followed by the intricate folding, tearing, and subsequent adlayer growth of these wrinkles. A salient feature of this method is the generation of intertwined graphene spirals and the transformation of the chiral angle inherent to one-dimensional (1D) wrinkles into a two-dimensional (2D) twist angle, interposing layers within a three-dimensional (3D) superlattice. Employing techniques such as seeded growth and substrate engineering allows for the precision-driven formation of layered stacks with predefined twist angles. The foundational principle is not only robust but also universally applicable, permitting its extension to other foldable 2D materials. Such an approach holds the promise of enabling the fabrication of miniaturized electronic components, encompassing capacitors, resistors, inductors, and superconductors.

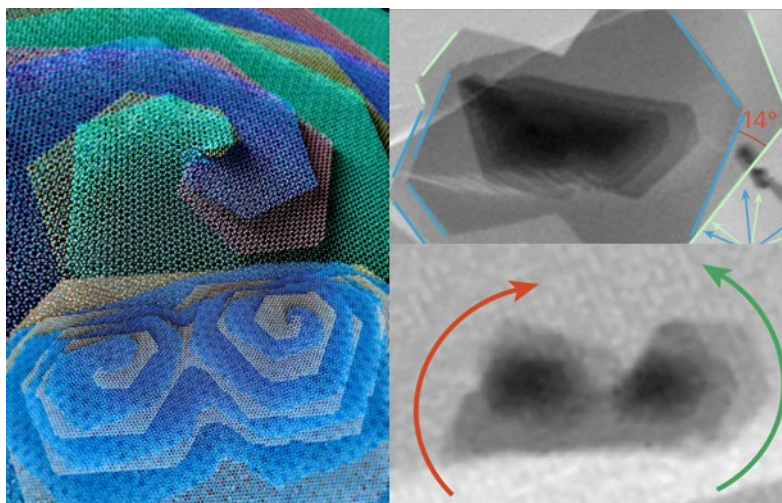


Fig.1. Spirals of twisted layer graphene with pre-defined twist-angle. Comparison between simulation and in-situ observation during CVD growth.