Vapor-Controlled Growth of Semiconducting Epitaxial Graphene

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Semiconducting epitaxial graphene (SEG) formed on the Si-terminated face of silicon carbide (SiC) has emerged as a highly promising 2D semiconductor, exhibiting a well-defined bandgap and ultrahigh room-temperature mobility [1]. However, achieving macroscopic homogeneity remains a critical challenge due to the complex and often non-equilibrium silicon sublimation dynamics in conventional confinement-controlled sublimation (CCS) [2]. In this work, we demonstrate that the morphology and structural order of SEG can be deterministically regulated by controlling the local silicon vapor pressure during high-temperature annealing. We systematically investigated the surface reconstruction dynamics of SiC(0001) using two distinct quasi-equilibrium growth configurations: the face-to-face (FTF) and face-to-graphite (FTG) methods. Our experimental results reveal that the FTF configuration establishes a highly confined micro-environment with a saturated Si vapor pressure, which thermodynamically drives extensive and sequential step bunching [3]. This dynamic coalescence of underlying substrate steps yields macroscopic, wide, and atomically flat terraces, allowing for the continuous nucleation and growth of large-area SEG [4]. Conversely, the FTG method alters the local mass transport, leading to a different Si vapor environment where substrate steps remain unmerged and narrow, consequently restricting the continuous growth area of the SEG domains [5]. Surface characterizations, including cryogenic scanning tunneling microscopy and Raman mapping, confirm that the SEG grown on the wide terraces in the FTF setup is structurally pristine and phase-pure. These findings highlight that modulating Si vapor pressure to intentionally induce step bunching is a deterministic mechanism for synthesizing wafer-scale, high-quality SEG, paving the way for next-generation 2D nanoelectronics.

References:
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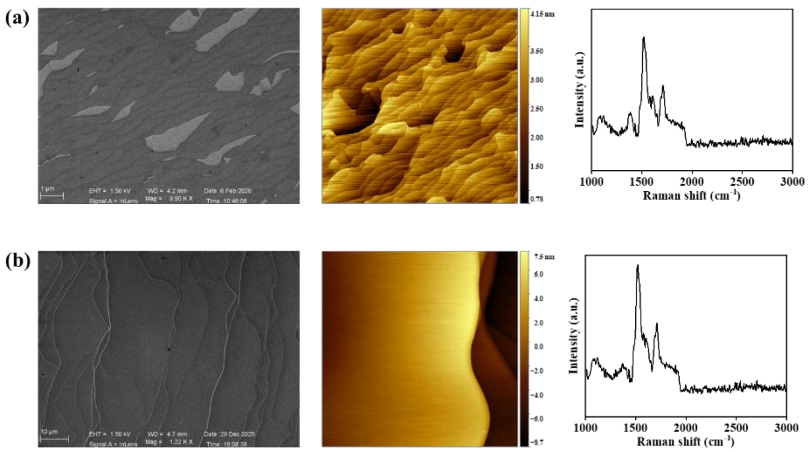

Fig. 1 Morphology and structural characterization of the fabricated samples. (a) SEM image, AFM topography map, and Raman spectrum of the sample fabricated via FTF; (b) SEM image, AFM topography map, and Raman spectrum of the sample fabricated via FTG.