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IT-12-O-2910 Shadow Dark-Field LEEM and Scanning Micro-LEED of Epitaxial Graphene on Ru(0001) and Ir(111) Surfaces

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Spatially resolved measurements using cathode lens microscopies have made notable contributions to the understanding of graphene layers that are customarily spatially inhomogeneous [1]. We have applied low energy electron microscopy (LEEM) and complementary micro-low energy electron diffraction (μLEED) to study the structure and morphology of single layer graphene (g) on Ru(0001) and Ir(111) surfaces, examples of strongly and weakly interacting substrates, respectively. Our investigations of g/Ru(0001) reveal rich structural non-uniformity that depends strongly on preparation conditions. When the g/Ru(0001) layer is prepared using chemical vapor deposition (CVD) by exposure to ethylene at high temperature, we observe strong streaking of superstructure diffraction spots (Fig. 1(a),(c)) for large area (3μm) illumination. This indicates the proliferation of small angle (<0.25°) lattice rotations in the graphene layer. Corresponding small-angle lattice rotational domains are visualized in “shadow” dark field LEEM images (Fig. 1(b),(d)) that are formed by selecting the rotated edge of the streaked superstructure spots using the contrast aperture. The presence of rotation domains also causes the sharp sets of μLEED superstructure diffraction spots around each integer order spot to rotate to-and-fro as a group about their respective stationary foci when the small μLEED illumination beam (250nm) is scanned across the surface. These scanning μLEED measurements provide detailed information about the rotation angle distribution and even indicate a net deviation from perfect alignment between graphene and substrate.

Although the length scale of the rotational domains in g/Ru(0001) can be pushed up to the sub-micron length scale by increasing the growth temperature (Fig. 1(d)), further improvements are limited by the diminishing growth rate at increasingly higher temperature for accessible ethylene pressure. On the other hand, massive single rotation domains can be fabricated by CVD if the crystal is first pre-loaded with carbon by dissolution of a single graphene layer. Although near perfect rotational order was observed (Fig. 1(e),(f)), scanning μLEED revealed substantial spatial variation of lateral periodicity that was not seen when small-angle rotational domains were present. Hence, fabrication of optimal uniform g/Ru(0001) is still elusive. Experiments on g/Ir(111) reveal that small angle rotational microstructure is similarly prevalent when the graphene lattice is nominally aligned with the substrate, but it is substantially suppressed in macro-domains with larger misalignments.

Reference

[1] K.L. Man and M.S. Altman, J. Phys.: Condens. Matter 24, 314209 (2012).

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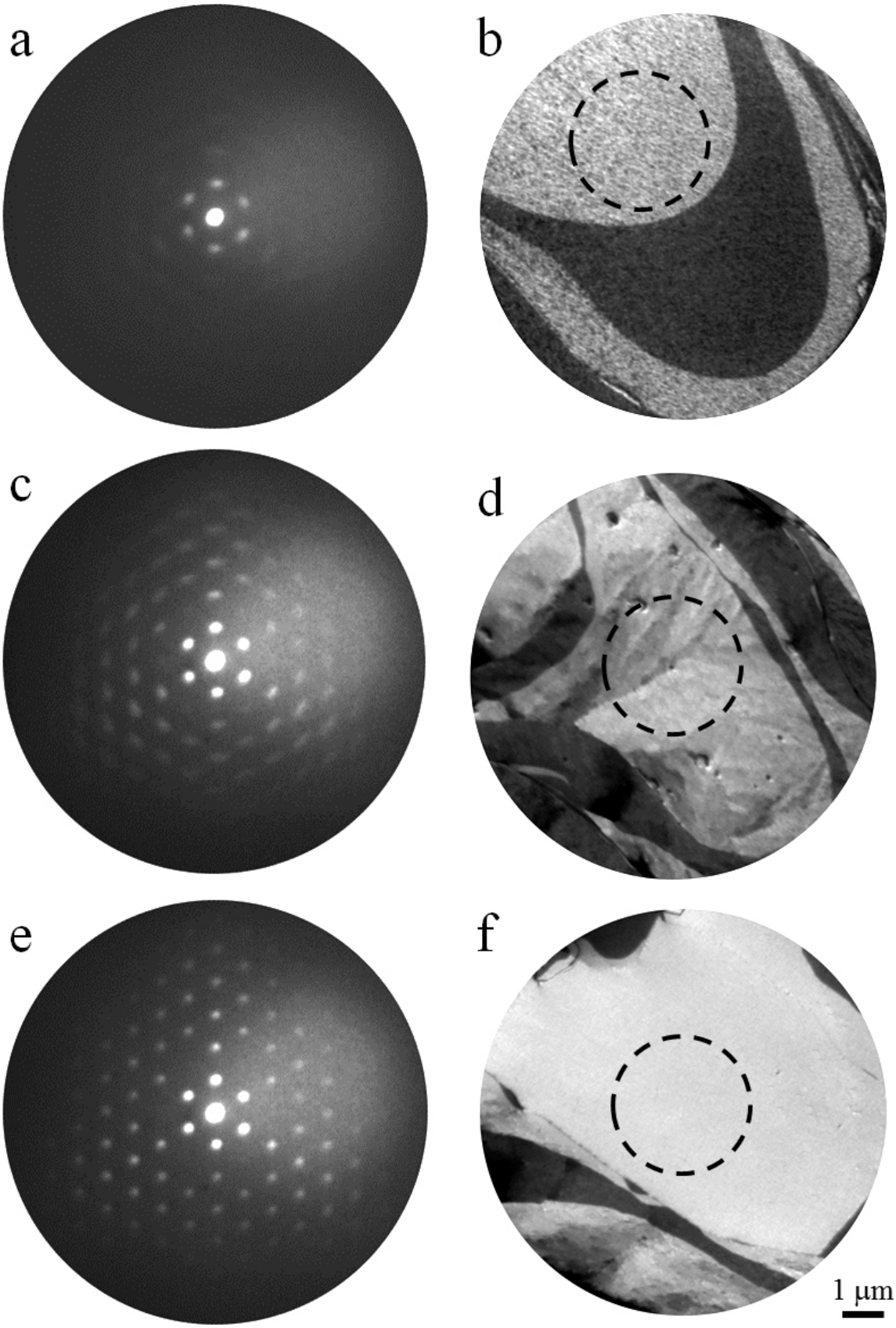

Fig. 1: (a),(c),(e) LEED patterns obtained from the areas indicated in (b),(d),(f) shadow dark-field LEEM images of g/Ru(0001). Graphene was prepared by CVD at (a),(b) 1100K; (c),(d) 1270K; (e),(f) 1300K on a preloaded substrate. Contrast fine structure in (b),(d) is due to small angle rotation domains. A uniform rotation domain is seen in (f).