Outline: Thin Film Nucleation, Growth, and Microstructure Evolution

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Chapter 1. The substrate: an introduction to surface structure/processes

a. surface energies: measurements and role in film growth
b. surface structure: examples of reconstruction and relaxation
c. terrace-step-kink structure: examples (STM)
d. surface diffusion
e. step-edge barrier and 2D kinetic roughening
f. corner barrier and 1D kinetic roughening.

Chapter 2. Thin film nucleation

a. the nanoscience of nuclei and small clusters: reduced cohesive strength, depressed melting point, increased 2D vapor pressures
b. thermodynamics of nucleation (a simple stability problem): examples
    1. capillarity-based atomic-scale models: examples
    2. wetting angle: examples (TEM, STM)
    3. graphene/fcc(111) moiré superstructure templates (STM, LEED)
c. kinetics of nucleation: examples (STM)
d. coalescence and coarsening: examples (TEM, STM videos)
e. early stages of film growth (experiment and simulation): examples
    1. anisotropic edge diffusion
    2. strain effects.

Chapter 3. 2D step flow and layer-by-layer epitaxial growth

a. introduction: Si on Si(001), a case study (STM, theory)
b. 2D step flow
    1. definition and requirements
    2. possible to achieve?
    3. role of buffer layers: examples
    4. experimental observations: He, x-ray, and RHEED scattering
c. layer-by-layer growth
    1. definition and requirements
    2. possible to achieve?
    3. experimental observations: He, x-ray, and RHEED scattering.

Thin Film, Nucleation, Growth, and Microstructure Evolution (cont.)

Chapter 4. 2D multilayer growth

a. experimental observations: STM vs. RHEED oscillations
b. simulations vs. experimental observations: examples
c. low-temperature epitaxy: fundamental limits
    1. critical epitaxial temperature T_{epi} vs. critical thickness t_{epi}
d. techniques for increasing t_{epi}
    1. surfactants: examples (STM and RHEED oscillations)
    2. hyperthermal beams: examples (XTEM).

Chapter 5. Heteroepitaxy and the role of misfit strain

a. elastic strain energy
b. edge, screw, and mixed dislocations: TEM, XTEM, & LEEM videos
c. relaxation mechanisms: elastic energy vs. misfit dislocations and surface energy
    1. misfit dislocations, critical thickness, strategies to decrease dislocation density: examples
    2. surface roughening, islanding, S-K growth: examples
d. quantum dot engineering: examples (STM, XTEM)
e. quantum wires (STM)
f. 2D layers: silicene4x4/Ag(111), silicene/ZrB_2(0001), MoS_2/Gr (STM, RHEED).

Chapter 6. 3-D polycrystalline growth and nanostructure evolution

a. nucleation: examples (TEM, AFM, STM)
b. coalescence: examples (TEM and STM videos)
    1. complete vs. incomplete: examples (STM)
c. coarsening: examples (TEM and STM videos)
d. grain boundaries in 2D materials: example Gr/Cu (STM and TEM)
e. grain boundary energies
f. grain growth: examples (TEM)
g. structure-zone models: experiment vs. computer simulations
h. oblique deposition and atomic shadowing.

Chapter 7. Film stress and texture evolution

a. thermal stress: examples
b. stress measurement: examples
c. tensile stress mechanisms: examples (TEM, XTEM)
d. ion-induced stress: examples
e. compressive stress mechanisms: examples (XTEM)
f. stress in superlattices and multiplayer systems
g. texture evolution: examples (AFM, XTEM, simulation).