

Direct Atomic-Scale Observation of Nanoparticles Coalescence Driven Nucleation and Growth in the TEM

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Unravelling dynamical processes of liquid droplets at liquid/solid interfaces and the interfacial ordering is critical to understanding solidification, liquid-phase epitaxial growth, wetting, liquid-phase joining, crystal growth, and lubrication process, all of which are linked to different important applications in material science.¹ Many studies have been reported with the indirect evidence of density fluctuations at liquid/solid interfaces on the basis of X-ray scattering methods, atomic force microscopy (AFM) and with the support of atomistic simulations.²

In this work, we observe the in-situ atomic-scale behavior of fabricated Bi droplets segregated on SrBi₂Ta₂O₉ by using aberration corrected transmission electron microscopy. We demonstrate ordered interface and surface structures for the droplets on the oxide at the atomic-scale and unravel a nucleation mechanism involving droplet coalescence at the liquid/solid interface. We identify a critical diameter of the formed nanocrystal in stabilizing the crystalline phase and reveal lattice induced fast crystallization of the droplet at the initial stage of the coalescence of nanocrystal with droplet. Further sequential observations show the stepped coalescence and growth mechanism of the nanocrystals at the atomic-scale. These results offer insights into the dynamic process at liquid/solid interfaces, which may have implications for many functionalities of materials and their applications.^{3,4}

References

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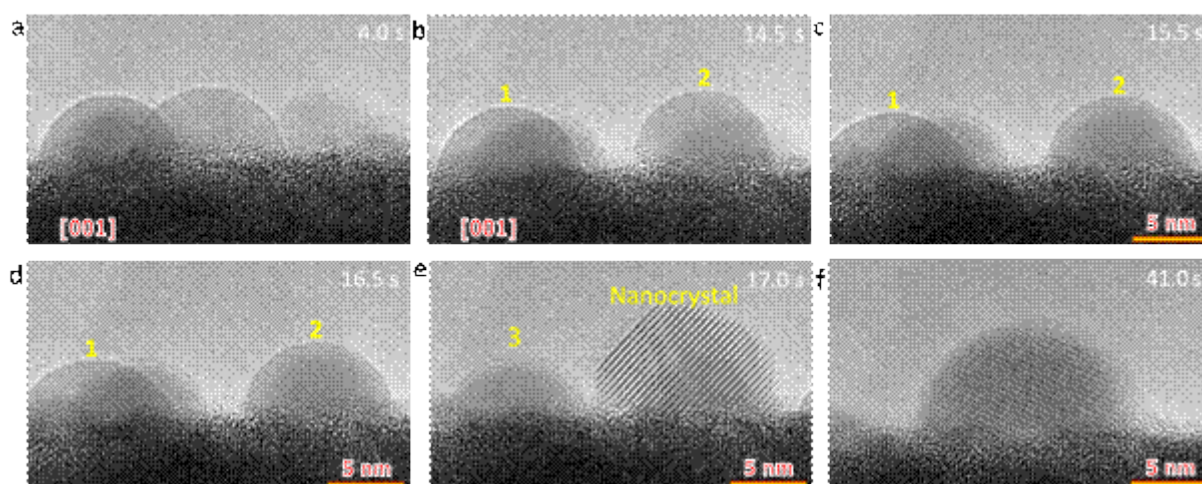


Figure 1. Droplet 1 and 2 coalescence induced crystallization at the Bi/SrBi₂Ta₂O₉ interface. The electron dose rate is $4.22 \times 10^4 \text{ e}^-/\text{\AA}^2 \cdot \text{s}$.

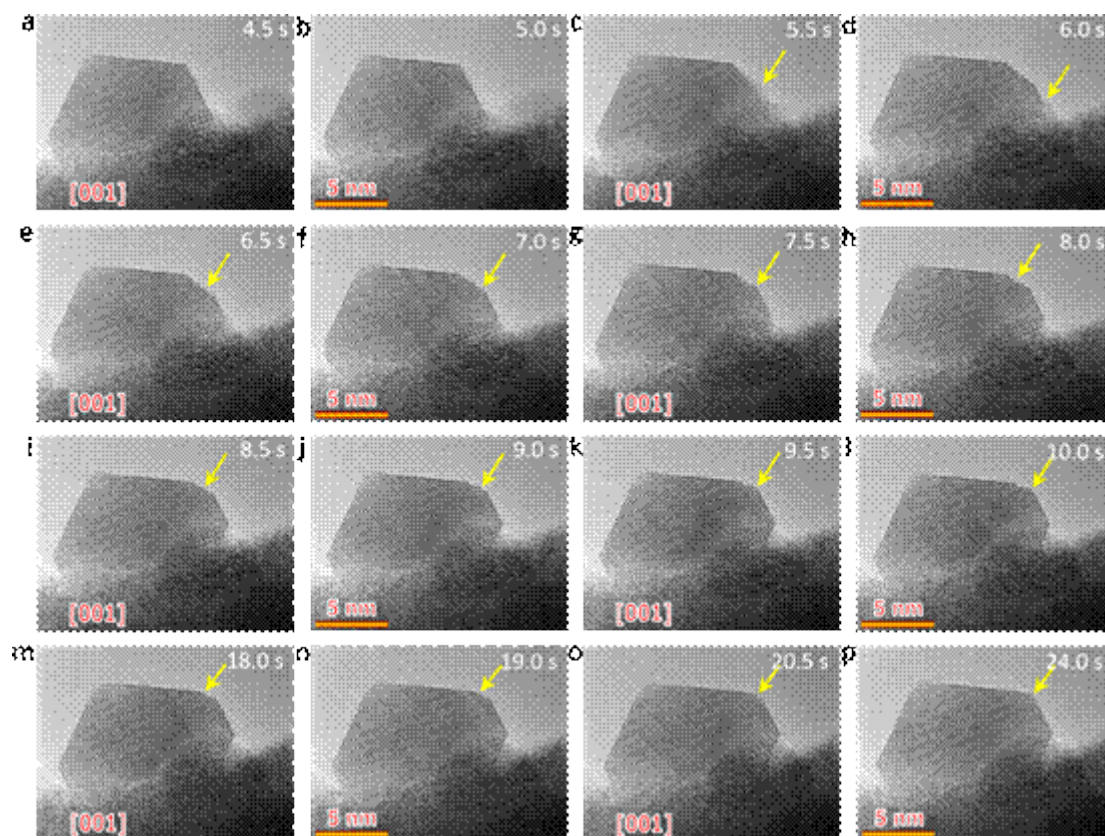


Figure 2. Coalescence of nanocrystal with droplet on the support and step-growth mechanism. a - e, HRTEM images showing the coalescence of nanocrystal with droplet on the support at the atomic scale. f - p, HRTEM images showing the atomic-scale observation of the step-growth on the supported Bi nanocrystal. The electron dose rate is $2.15 \times 10^4 \text{ e}/\text{\AA}^2 \cdot \text{s}$.