Dynamics of an interfacial bubble controls adhesion mechanics in a van der Waals heterostructure

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Devices using two-dimensional (2D) materials are promising for various applications because of their tunable properties. 2D van der Waals heterostructures (vdWH) can result in novel functionality and the interfacial structure, disorder, and relaxation determine the emergent electrical properties. Bubbles at the vdWH interface can modify the interfacial structure. Our work probes the dynamics of a bubble at the interface of a graphene-hBN vdWH by using it as the drumhead of a NEMS device. NEMS devices are exquisite sensors of both external forces as well as the internal state of the device. We use drum resonators with different interfacial conditions so that there are either no bubbles, few small bubbles (≈ 100 nm in size), or a single large bubble (≈ 700 nm in size). By measuring the evolution of the resonant frequency and spatial mode shape with an electrostatic gate, we show that the hysteretic detachment of layers of vdWH is triggered by the bubble growth. The bubble growth takes place due to the concentration of stress resembling the initiation of fracture. The small bubbles at the interface of heterostructure do not result in delamination as they are smaller than the Griffith's critical fracture length. Our study offers insight into frictional dynamics and interfacial fracture at nanoscale and has implications for the design of nanoscale laminates and composites.

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