Multi-scale correlative investigations of failure mechanisms in two-dimensional crystalline polymers

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Two-dimensional (2D) polymer thin films hold great potential for advancing microelectronics and flexible electronics [1]. However, their integration into nanodevices remains challenging due to unresolved issues related to mechanical integrity, as the damage and failure mechanisms of 2D polymers are not yet well understood [2]. This study systematically investigates an interfacial-synthesized 2D crystalline polymer (2D polyimine) [3] to elucidate its failure mechanisms under different damage processes.

To evaluate patterning-induced failures, focused electron beam (FEB), focused ion beam (FIB), and mechanical patterning techniques were examined [4]. Based on this evaluation, a beam-free transfer and patterning method was developed, enabling *in-situ* tensile testing in a transmission electron microscope (TEM, Libra200, Carl Zeiss). The complete failure process of 2D polyimine films under in-plane mechanical stress was captured in real time, revealing unique fracture dynamics and crack propagation behaviors. Additionally, distinct fracture modes across different grain orientations underscore a crystallography-driven fracture mechanism, further supported by atomistic insights from Density-Functional Tight-Binding (DFTB) simulations [5].

These findings enhance the fundamental understanding of structure-property relationships in 2D polymers, providing valuable guidelines for designing novel 2D polymers with tailored mechanical reliability and optimizing patterning strategies for device integration.

References

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