Unveiling microtubule fracture dynamics: A comprehensive examination of the influence of lattice defects on the breakage process of microtubules

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Abstract

Microtubules (MTs), crucial to many cellular functions, are tube-like structures formed by a quasi-crystalline arrangement of $\alpha\beta$–tubulin heterodimers.
Two parameters that are major determinants for MT stability and dynamics are the lattice binding energy and anisotropy (defined as the ratio between the longitudinal and lateral binding energies).

Despite considerable effort on comprehending the dynamics of the MT tip, in particular the so called dynamic instability, the dynamics within the "bulk" MT lattice have received little attention.

Recent experimental findings revealed that MTs often present dimer and monomer sized vacancies along their shaft, resulting in structural defects that compromise their shaft integrity and may interfere with the dynamic instability at the tip.

Here we employ kinetic Monte Carlo simulations, as well as analytical approaches, to study the defects dynamics in the MT shaft and their effects on MT breakage in the absence of free tubulin dimers.
Our findings highlight the significant role of initial defects in the fracture propagation dynamics. Furthermore, comparison with experiments allows us to identify lattice binding energies and anisotropies that accurately reproduce experimental observations of fracture times and lengths.

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