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Failure of disordered materials as a depinning transition

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Crack propagation is the fundamental process leading to material failure. However, its dynamics is far from being fully understood. In this work, we investigate both experimentally and theoretically the far-from-equilibrium propagation of a crack within a disordered brittle material. At first, we focus on the average dynamics of a crack, and study the variations of its growth velocity v with respect to the external driving force G [1]. Carefully measured on a brittle rock, these variations are shown to display two regimes: above a given threshold G_c, the velocity evolves as a power law $v \sim (G - G_c)^{0.8}$, while at low driving force, its variations are well described by a sub-critical creep law, characteristic of a thermally activated crack propagation. Extending the continuum theory of Fracture Mechanics to inhomogeneous media, we show that this behavior is reminiscent of a dynamical critical transition: critical failure occurs when the driving force is sufficiently large to depin the crack front from the material heterogeneities. Another way to reveal such a transition is to investigate the fluctuations of crack velocity [2]. Considering a crack at the heterogeneous interface between two elastic solids, we predict that its propagation occurs through sudden jumps, with power law distributed sizes and durations. These predictions compare quantitatively well with recent direct observations of interfacial crack propagation [3]. Such an interpretation of material failure opens new perspectives in the field of Engineering and Applied Science that will be finally discussed.

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