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Nanoscale Step Formation on Highly Oriented Pyrolitic Graphite Cleavage Surfaces

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Summary

By a careful peeling of a thin film of graphene sheets from a highly oriented pyrolitic graphite (HOPG) sample, nanoscale steps of one or several multiples of graphene sheet spacing are commonly formed on the cleavage surface. These steps have been shown to exhibit novel electrical and other properties for potential nanodevice applications. However, it has not been clear how these steps are formed during the peeling process and how their characteristic features such as the height and density can be controlled. The step formation has been sometimes attributed to pre-existing defects in a HOPG sample. In the present work, we propose that these nanoscale steps are formed by tearing a stack of graphene sheets sandwiched between the film being peeled and the sample substrate. This process involves the cleavage fracture breaking the Van der Waals bonds between graphene sheets and the tearing fracture of individual graphene sheets breaking the covalent bonds within the basal plane. We have developed a continuum model to simulate the process and study the underlying physics in the step formation. The cleavage fracture toughness is extracted from a commonly used Leonard-Jones potential for graphene sheet interaction. The step height is shown to be determined by the tearing to cleavage toughness ratio, as a bifurcation phenomenon of crack interaction.