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Glancing ion incidence on a graphite-supported graphene flake: Lift-off vs welding



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ABSTRACT

Using molecular-dynamics simulation, we study the impact of 0.5 keV Xe ions at glancing incidence (80° from the surface normal) on a graphene flake supported on a (0001) graphite substrate. The step forming at the ascending edge of the flake allows the entrance of glancing-incidence ions into a subsurface channel between graphene layers. We find that subsurface-channeled ions have a high probability to lift the flake off the substrate, while non-channeled projectiles rather damage the flake leading eventually to welding the flake to the substrate by the formation of sp^3 bonds.

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1. Introduction

The interaction of ion irradiation with graphene sheets is of considerable interest, and has recently been reviewed by Krasheninnikov and Nordlund [1]. More recently, oblique and glancing ion incidence on graphene layers was studied; the graphene layers were supported by a metal [2,3] or a semiconducting substrate [4]. These studies provided information about defect formation, ion trapping, and the phenomena of interface and subsurface channeling.

Glancing ion incidence on metals has been studied in considerably greater detail, both by experiment and by simulation [5–11]. Such glancing impact gives rise to the phenomenon of subsurface-channeling where the projectile is channeled immediately under the surface. In this channeling mode the ion creates characteristic damage, such as vacancy islands aligned with the ion incidence direction (projected onto the surface) and even nano-grooves. This ample body of evidence for metallic targets is supplemented by more scarce studies of semiconductors [12,13] and ionic surfaces [14].

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Besides metallic or semiconducting substrates, also a graphitic substrate may be used. Indeed a graphene flake on a graphitic substrate naturally appears as an adatom island there. The interaction of ion irradiation with flat – but not with graphene-flake-covered – graphite surfaces has been studied intensely in the past. Experimental studies of ion irradiation on graphite focused on defect generation [15], but also on ion penetration and the sputtering induced [16]. Defect formation under ion irradiation of graphite was extensively studied by Nordlund et al. [17-19], and these results were also extended to cluster impact [20-22]. Radiation effects in graphite are reviewed by Burchell [23]. Most recently, Christie et al. [24] published a detailed study of the evolution of collision cascades in graphite. Many studies were devoted to cluster impact. Webb et al. [25] studied fullerene impacts into graphite and compared its comparison to experimental data obtained by an oxidation technique. Reimann et al. [26] studied experimentally damage creation by metal cluster impact into graphite, and Henkel and Urbassek [27] analyzed this scenario theoretically. These studies were later followed by investigations of fullerene and gascluster impacts [28,29].

Desorption from a graphite substrate induced by cluster impact was studied, but usually cluster projectiles were used. Webb [30] used fullerene projectiles to desorb molecules adsorbed on the surface, while Baranov et al. and Anders et al. use large metal cluster projectiles to desorb Au clusters [30–32]. Kornich et al. [33,34]

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