Nanotents –2 nm void-formation and self-healing in 2D monolayers on metals

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Abstract:

At room temperature, it is quite challenging to immobilize single atoms, in particular the least reactive noble gases. Conventional ion implantation possesses this capability, but it does not permit much control over the randomness of the involved processes. However, with the single layers of hexagonal boron nitride (*h*-BN) or graphene, site-selective immobilization of atoms at surfaces becomes feasible [1]. The *h*-BN nanomesh is a corrugated honeycomb structure, which consists of two bonding regions, the 'pores' with 2 nm diameter, and the surrounding 'wire' regions where the *h*-BN is weakly bonding to the substrate [2,3].

In the present study, we demonstrate that the *h*-BN nanomesh, which acts as ultimately thin "rainfly", can trap argon atoms at distinct subsurface sites and form so-called "nanotents" structure (Figure 1). Remarkably, these "nanotents" are stable at room temperature and survive exposure to air. In-situ variable temperature measurements show that nanotents decrease in number while growing in size upon annealing to 450 K [4]. Further annealing to 900 K induces the "can-opener" effect: highly regular 2 nm *h*-BN flakes or "lids" are cut out from the *h*-BN monolayer and 2 nm voids form on the *h*-BN surface. We assign the "can-opener" effect to the vacancy defects generated during the Ar penetration. Higher temperature (> 1000 K) annealing treatment leads to the "self-healing" of the *h*-BN monolayer [5]. Systematic measurements reveal that the entire process, including nanotent formation, "can-opener" effect and nanomesh "self-healing", is well controlled and repeatable. The study bases on scanning tunneling microscopy, photoemission, molecular dynamics and density functional theory calculations. The reported effects are robust and quite general: they are also observed in graphene on ruthenium [6], for neon and rubidium atoms [7]. Such nanoporous 2D membranes then can be transferred on arbitrary substrates.

References:

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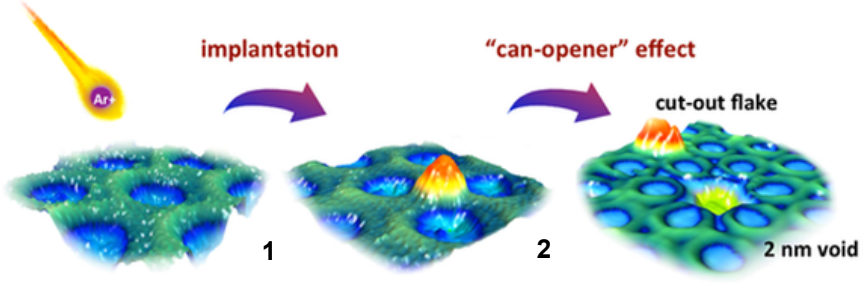

Figure 1: Schematic illustration displays the two-step process of Ar implantation upon ion irradiation (1) and the "can-opener" effect induced by subsequent annealing (2).