Intercalating cobalt between graphene and iridium(111): kinetics from edges and mechanical stress in graphene

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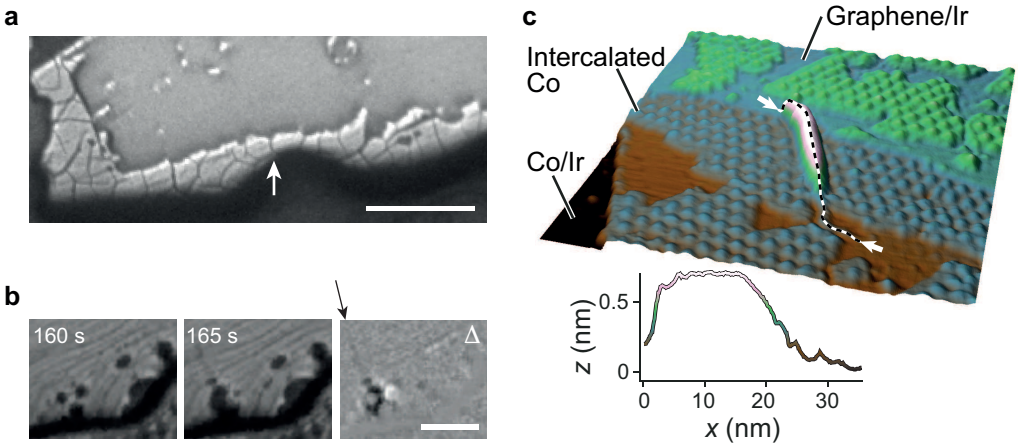
Since its discovery, the ability to modify and control the properties of a graphene layer has been a central issue in the view of potential applications. The intercalation of foreign atoms or molecules between a graphene sheet and its substrate offers a wealth of opportunities to modify graphene's properties. Intercalation is in fact an established route to functionalize graphene from below, to decouple it from its substrate and to modify the properties of the intercalated layer [1,2]. Identifying and selecting the intercalation pathways is therefore of crucial importance for the preparation of advanced multi-layered functional materials based on high quality graphene.
Here we focus on Co intercalation between graphene and Ir(111) taking place at the edges of graphene flake which we monitored by real time low energy electron microscopy (LEEM) and by scanning tunnelling microscopy (STM). Mass transport through graphene edges is described using a phenomenological model, which allows estimating the energy barriers involved in the process [3]. We find that these energies differ by a few tens of meV from one location to another along the graphene edge. Moreover we demonstrate that graphene is a mechanically active membrane which, upon the intercalation process, deforms and opens nano-channels (wrinkles) that allow efficient mass transport while storing and releasing elastic energy via lattice distortions [4].



a. LEEM image showing a network of wrinkles in graphene formed upon Co intercalation. **b.** Two LEEM images and their difference (Δ), recorded during Co intercalation showing the formation of the wrinkle (marked with an arrow). **c.** Three-dimensional representation of a STM image (60×40 nm^2) revealing compact ML Co islands intercalated below graphene on two Ir(111) terraces separated by an atomically-high Ir step edge. A wrinkle is observed, whose apparent height (z) profile taken between the two arrows along the dotted line is shown. Scale bars are 2 and 0.5 μm in **a** and **b** respectively.

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