

# Low-temperature rapid thermal CVD of nanocrystalline graphene on Cu thin films

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Chemical vapor deposition (CVD) of graphene onto Cu substrates is a very promising approach for large-scale production. When dealing with Cu thin films instead of foils, there are additional problems related to the stability of the film at high temperatures. We show that the film rupture and agglomeration can be prevented by monitoring *in-situ* dewetting dynamics of the catalyst. We investigated the

possibility to perform CVD of graphene onto Cu films, 200 nm thick, at low-pressure conditions, with ethanol or methane as C precursors. Same recipes applied on Cu foils lead to worse results highlighting the important role played by the substrate thickness to achieve a high catalytic activity. The influence on the deposition quality of parameters such as time, temperature and hydrogen flow is then discussed.

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**1 Introduction** Large-scale production of graphene is the first step that, once reached with a good reliability, will lead to a large integration of graphene in devices. Chemical vapor deposition (CVD) allows the growth of polycrystalline graphene monolayers with grain dimensions that can vary from hundreds of nanometers up to few millimeters. The best results in terms of grains dimension have been obtained on Cu foils [1] and recently on Pt foils [2] suggesting foil supports as a good candidate for large-scale production. The main drawback of deposition onto foils is the need for a transferring process that is mainly realized through an intermediate step strengthening the layer by means of a polymer [3].

A promising approach to mitigate this problem is to reduce the substrate thickness and several studies have been carried out centered mainly on Cu [4–8] and Ni [8–10] thin films. Moreover, further studies have been reported regarding the relation between crystallinity of the Ni thin films and the graphene deposition quality [11], while on Cu thin films some results are given on the influence of the grain orientation ascribing a higher quality to growth onto  $\langle 111 \rangle$  facets [4, 12].

Graphene deposited on films can be transferred with the same methods used for foils, but also other approaches can be followed such as face-to-face transfer [13], rigid

transfer [14] or avoiding the use of a polymer and transferring graphene onto silanized SiO<sub>2</sub> [15]. Moreover, the dewetting phenomenon [16], which is generally recognized as being a limiting factor for the use of thin films as suitable substrates for graphene deposition, has been exploited to let graphene lay down on the SiO<sub>2</sub> substrate beneath the Cu film [17, 18]. All these possibilities suggest a much wider spectrum of applications with respect to graphene grown on foils and envisage new solutions that can lead to cheaper and more effective production processes. In conclusion, the choice of thin films is related to the promising opportunities given by integration in the current microelectronics technology.

Due to dewetting, deposition temperatures lower than the ones used in foils are advisable with thin films. Moreover, lowering temperature could reduce the stress of the sample, a wider range of substrates could be used, and, finally, in an industrial perspective, less power is needed.

Ethanol seems a promising precursor, due to its lower cracking temperature [19], and has been recently used to deposit graphene on Cu foils at temperatures lower than on methane [20, 21].

In this paper we present our results in low temperature nano-crystalline graphene growth on thin films by ethanol and methane, investigating different deposition conditions