

RESEARCH ARTICLE

Raman analysis of strained graphene grown on dewetted cobalt

Giampiero Amato^{1,2}  | Federico Beccaria^{1,3} | Elisabetta Landini³ | Ettore Vittone³

¹Nanoscience and Materials Division, INRIM, Strada delle Cacce 91, 10135 Torino, Italy

²Department of Science and Technological Innovation, University of Eastern Piedmont “A. Avogadro”, Viale T. Michel 11, 1512 Alessandria, Italy

³Department of Physics and NIS Interdepartmental Center, University of Torino, via Pietro Giuria 1, 10125 Torino, Italy

Correspondence

Giampiero Amato, Department of Science and Technological Innovation, University of Eastern Piedmont “A. Avogadro,” Viale T. Michel 11, 1512 Alessandria, Italy.
Email: giampiero.amato@uniupo.it

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Abstract

Graphene grows onto cobalt by means of diffusion of carbon atoms during the isothermal stage of exposure to hydrocarbon precursor, followed by precipitation during cooling. This method, largely applied with nickel catalyst, is known to produce continuous, but not uniform, layers with the concurrent presence of mono- and poly-graphene areas. With the aid of Raman mapping of graphene still lying onto its catalyst, we are able to consider the possible origins for the observed distortions of the phonon modes with respect to the well-known picture of the monolayer material. Optical effects, doping, the presence of multi-layered islands, and strain are kept into account. It is shown that some observations can be interpreted in terms of the occurrence of isotropic strain with the uniaxial component superimposed at the metal discontinuities. Strain is proposed to originate from the difference between the thermal expansion coefficients of graphene and cobalt. The present paper shows that inhomogeneities in graphene grown onto catalysts with high C solubility are not always directly related to excess of precipitation. The observation of strain in as-grown graphene opens the possibility of tailoring the electronic density of states via strain engineering directly during growth.

KEYWORDS

chemical vapor deposition, cobalt, graphene, micro-Raman, strain

1 | INTRODUCTION

Since its experimental discovery in 2004,^[1] the interest of the scientific community for graphene resulted in numerous publications, both on its production^[2,3] and applications.^[4] Chemical vapor deposition (CVD) is one of the most used techniques, mainly on Cu^[5] and Ni^[6,7] substrates, whereas Co has not received the same attention.^[8] Although in Cu, the graphene growth process is limited to the catalyst surface, it is well known that in Ni or Co, the C solubility is about two orders of magnitude higher than in Cu, leading to C diffusion into the catalyst during the isothermal exposure to the gas source,

followed by the graphene growth by C precipitation in the following cooling stage.^[9]

The most relevant difference on the growth mechanism of graphene on Co and Ni stems on the different heat of precipitation of C into the metal substrate, as highlighted in Amato et al.^[10] Actually, Hasebe et al.^[11] reported about a value for the heat of precipitation Δ in Co about twice than in Ni at temperatures below its Curie temperature ($T_C = 1121^\circ\text{C}$), because of the magnetic contribution in the calculation of the enthalpy. Because the graphene growth is normally done around 1000°C , a temperature lower than $T_C(\text{Co})$, but higher than $T_C(\text{Ni})$, the thermally activated law describing the C solubility (β)