Increasing the catalytic activity of molybdenum carbide for graphene growth via molybdenum layer properties

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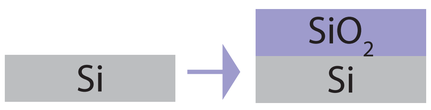
INTRODUCTION

Chemical vapour deposition (CVD) is known as the most promising route for industrially applicable wafer scale graphene synthesis. The CVD process mainly relies on the decomposition of a gaseous carbon source on a metal catalyst at high temperatures. Due to the e.g. inhomogeneous out-diffusion of carbon and metal groove formation, uniform graphene synthesis is still challenging. A new promising catalyst for uniform mono and multi-layer graphene (MLG) synthesis with high temperature stability is Mo_2C, having noble metal like catalytic properties and low cost[1,2].

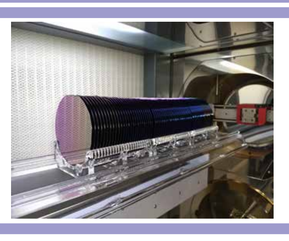
Unlike traditional graphene catalyst materials, Mo_2C is not directly deposited but is formed by a rapid transformation of a Mo layer directly after exposure to CH_4 at high temperature. The properties of the initial Mo layer, such as purity and density, are critical for the formed Mo_2C structure and also the subsequent graphene nucleation. Previously, the number of graphene layers showed to be different for Mo foils and thin films[2] but the influence of the Mo properties is not investigated. In this work, the relation is studied between graphene growth and the properties of the as deposited Mo layers before CVD, in particular the effect of Mo oxygen content and density.

PROCESS FLOW AND RESULTS

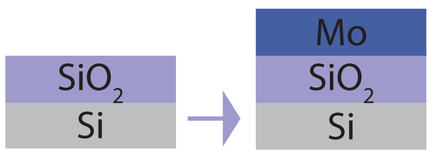
Dry oxidation of Si wafers

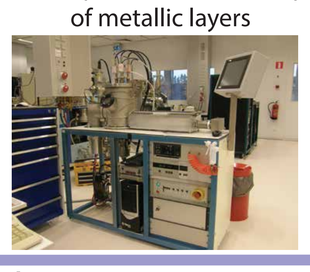


SiO_2 (300 nm) serves as a diffusion barrier in the CVD process

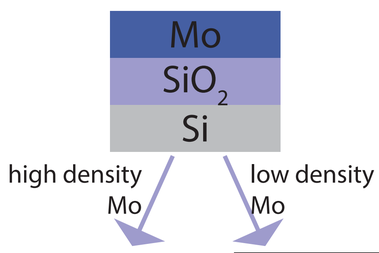


Sputtering of Mo layer

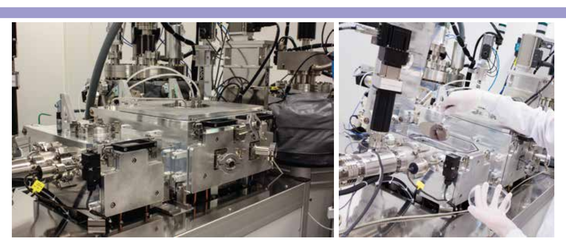


	DEPOSITION SYSTEM 1 Sputter system for deposition of films with sub-nm accuracy, with possibility of ion polishing during deposition and substrate bias	DEPOSITION SYSTEM 2 Single wafer sputter coater for deposition of metallic layers
		
	Low sputter pressure ↓ High deposition energy	High sputter pressure ↓ Low deposition energy
Density from X-Ray Reflectrometry	High about 10.2 g/cm³	Low about 8.8 g/cm³
Roughness from Atomic Force Microscopy	Very low R_q = 0.3 nm	Low R_q = 1.0 nm

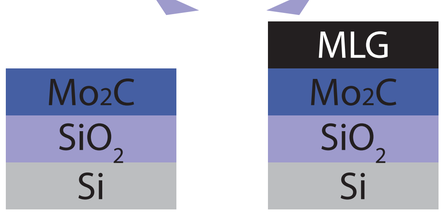
CVD progress

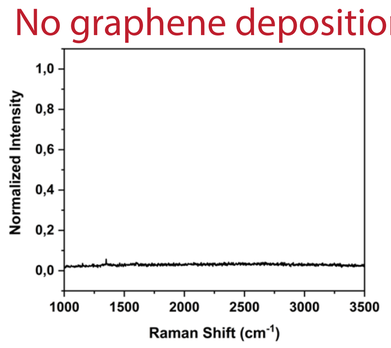
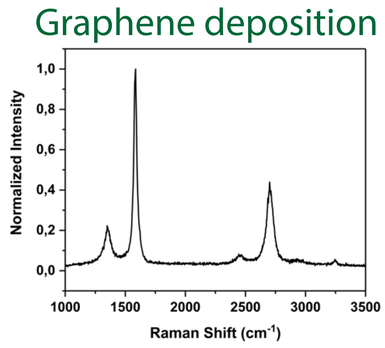
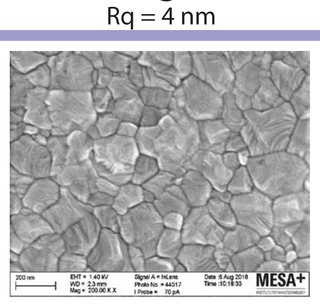
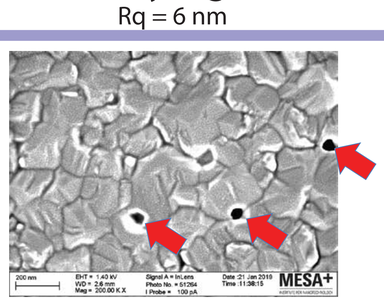


Cold wall reactor chamber
at 1000C using a feedstock of CH_4, H_2 and Ar



AFTER CVD progress



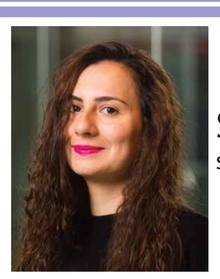
	No graphene deposition	Graphene deposition
Graphene growth from Raman spectroscopy		
Roughness from Atomic Force Microscopy	High Rq = 4 nm	Very high Rq = 6 nm
Defects Observed by Scanning Electron Microscopy	 No pinholes visible	 Pinholes visible

CONCLUSION

Results obtained from samples deposited under conditions varying the oxygen content and density show that samples with low density generally lead to graphene growth, in contrast to samples with high density. Additionally, the presence of excess oxygen may play a role in inhibiting graphene growth at higher oxygen levels. The importance of density is tentatively explained by the formation of defects in the low density layers, serving as nucleation points for graphene growth. This suggestion is supported by SEM images, which show that when starting from low density Mo layers, the resulting structure is much more open with increased surface area to volume ratio, resulting in much higher catalytic activity.

These results show that the structure of the initial Mo layer has a profound effect on the graphene growth process, and as such should always be considered in any study of graphene growth on such, and likely similar, catalysts.

CONTACT INFO



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