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DIRECT GROWTH OF GRAPHENE ON MOS_2: TOWARDS VAN DER WAALS HETEROSTRUCTURES

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INTRODUCTION

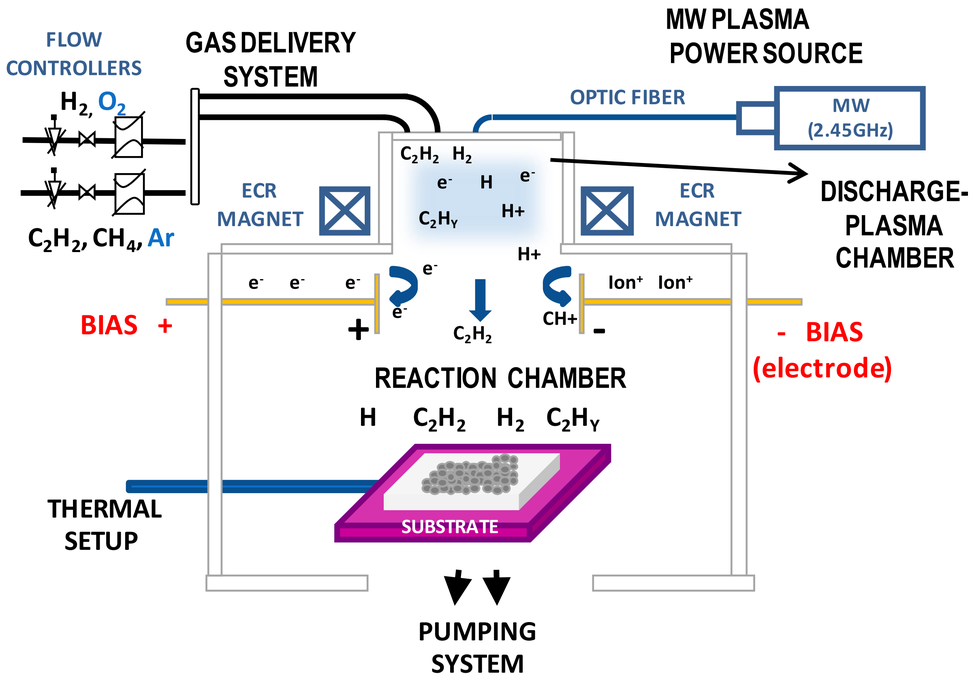
Heteroepitaxial growth of ultrathin films of semiconducting materials, conforming heterostructures, represent the main foundations of numerous modern devices. Recently, 2D semiconducting materials combined into van der Waals multilayers have emerged as an appealing option to conform semiconducting heterostructures with outstanding properties, without the typical interfacial lattice-matching constraints encountered in conventional heteroepitaxial (III-V) growth. Up to now, the production of these Van der Waals structures relies on transfer processes for research purposes with limited production yield. Therefore, to take advantage of this superlative properties, a scalable method to directly growth 2D materials heterostructures is a priority in this field.

Recently, we devised new protocols to directly growth graphene on semiconducting oxides at low temperature by using plasma-CVD [1,2]. CVD is a well-known technology to deposit 2D materials and thin films and with the plasma assistance the process is performed at low temperature (<500ºC) preserving the substrate surface.

In this contribution, we are extending our approach to directly synthesize graphene on transition metal dichalcogenides (MoS_2) by plasma-CVD exploring the feasibility of direct synthesis of van der Waals heterostructures [3]. The motivation to select MoS_2-graphene junctions is based on the ultrahigh responsivity of this hybrid contact under illumination resulting in a productive conversion of light into electrical current. The methodologies shown are intrinsically pure, scalable and represent a step forward in the direct growth of van der Waals heterostructures.

PLASMA TECHNIQUE & EXPERIMENTAL SET-UP

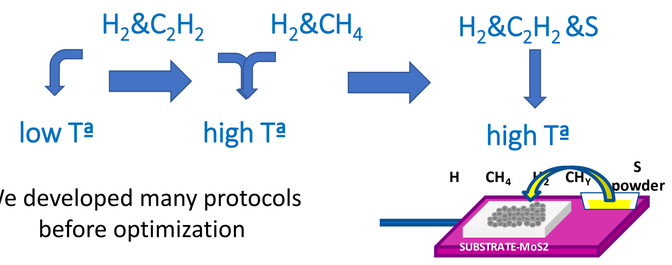
Electron Cyclotron Resonance
Plasma Assisted Chemical Vapor Deposition (ECR-CVD)



Instrumentation: Discharge chamber; plasma activation. Reaction chamber; synthesis-growth. Gas delivery system; flow controllers to insert gases to the plasma chamber. Power source; plasma activation via an optic fiber coupling the electric power to the plasma chamber for gas dissociation. Allow deposition at low Tª. Bias electrodes: screening e- and ion+. Only neutrals reach the sample substrate. Thermal setup: heater & substrate holder. Pumping system: two stage, rotatory and turbomolecular.

GROWTH PARAMETERS

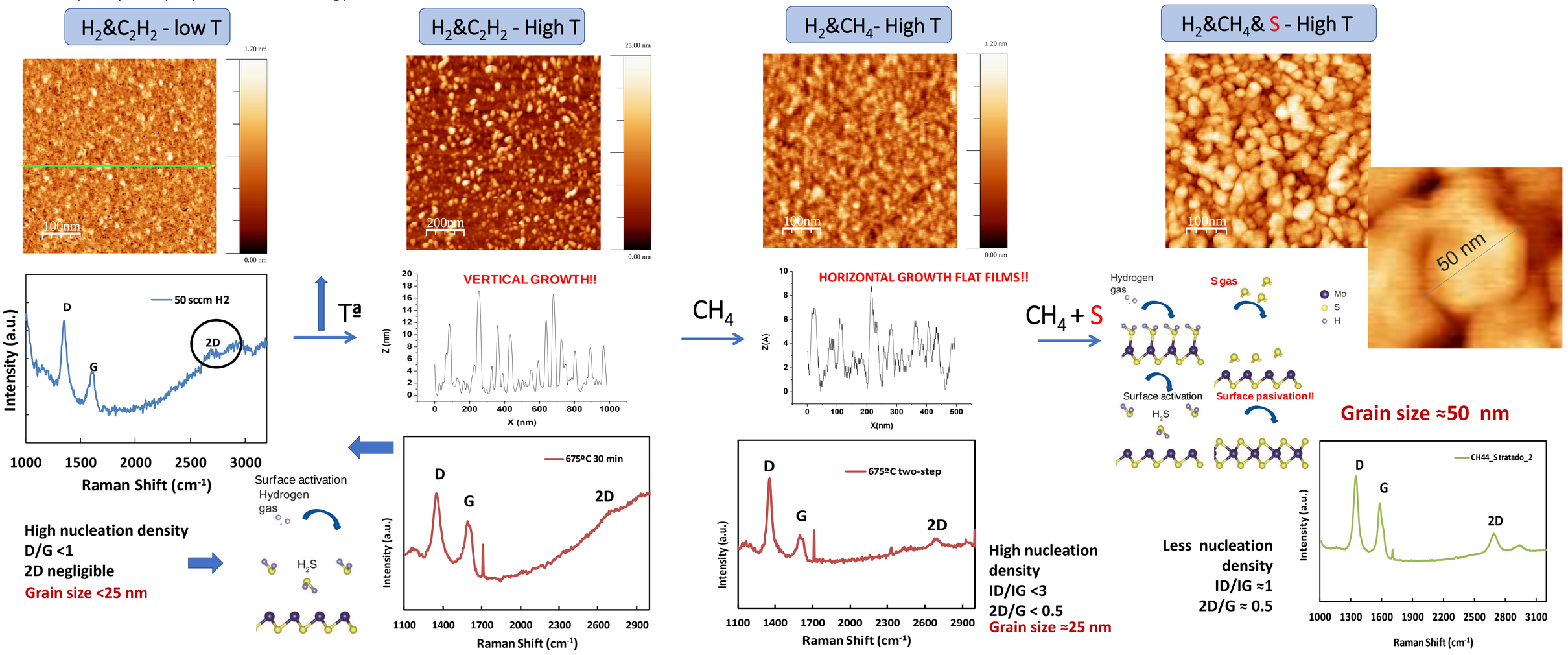
- **Carbon Precursor: C_2H_2 -CH_4**
- **Gas Carrier (Diluent): H_2 (helps in graphitization)**
- **Tª: 550ºC-675ºC**
- **Pressure: ≈ 10^{-2} mbar**
- **Gas pressure ratio: (H_2/C_2H_2)\|\|(H_2/CH_4)**
- **Evaporation of S powder**



We developed many protocols before optimization

EXPERIMENTAL RESULTS

The graphene films are characterized in terms of morphology (AFM), chemical structure and composition (Raman). We identify the substrate activation as the main limiting factor to improve the material quality and propose a new strategy to overcome this drawback.



CONCLUSIONS & OUTLOOK

- Growth with hydrogen and acetylene at low temperature results in small grain size and low quality. At high temperature vertical growth.
- Growth with hydrogen and methane at high temperature results in high quality but small grain size. We relate this effect with Hydrogen gas activation and Sulphur release.
- With added Sulphur, we improved the graphene material. Grain size is over 50 nm and with high crystallinity . We guess that the effect is related to sulphur passivation.
- On-going work: we continue playing with parameters to improve the grain size and the film quality. We will analyse the interface with surface techniques in order to asses the chemical state.

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