In-Situ SEM Etching Observation of the Graphene Layers by O_2, H_2, and CO

Hossein MIRDAMADI[1], Michal DYMÁČEK[2], Tomáš ŠIKOLA[1,2], Petr BÁBOR[1,2], Miroslav KOLÍBAL[1,2]

[1] CEITEC BUT, Brno University of Technology, Purkyňova 123, 612 00 Brno, Czech Republic,
[2] Institute of Physical Engineering, Brno University of Technology, Technická 2, 616 69 Brno, Czech Republic
sayed.hossein.mirdamadi.khouzani@ceitec.vutbr.cz

The electronic properties of graphene are significantly influenced by the shape and size of its layers. Additionally, it is possible to control the electronic states in graphene-based applications by interacting with adsorbed species and by intercalating atoms and molecules between graphene and the substrate, known as the van der Waals gap. Understanding the processes leading to intercalation or adsorption is crucial, though it is a complex issue. A practical approach for studying these processes is in-situ microscopy, which allows for monitoring and evaluating the dynamics during various species' etching of graphene stacks [1]. This contribution presents a systematic study assessing the interaction of oxygen and hydrogen molecules (isothermal etching) with the underlying graphene layer(s). This experiment provides insights into the interaction strength of both graphene-graphene and graphene-substrate interfaces. Initially, a graphene layer was synthesized on a Pt wire at elevated temperature using ethylene (C_2H_4) gas as a precursor within the ultrahigh vacuum (UHV) scanning electron microscope (SEM) chamber. To achieve multilayer graphene in an inverted-wedding-cake configuration, the sample was cooled to different temperatures (900 °C, 950 °C, and 1000 °C) after the first layer grew, resulting in carbon segregation from the Pt substrate and the formation of multilayer graphene islands. Subsequently, the samples were exposed to O2 or H2 (similar to [2]) or CO to monitor the etching behavior of the first layer and that underneath. The process of growing and etching the graphene layers will be presented in a series of movies, thanks to SEM observation during the experiment. The acquired data reveal surprising details of the intercalation process and enable quantifying essential parameters such as diffusion length and activation energy of the relevant processes.

References

[1] Wang, Zhu-Jun, Nature Communications, 1 (2016) 13256.
[2] Wei, Wei, Science China Chemistry, 5 (2017) 656-662.

Figures

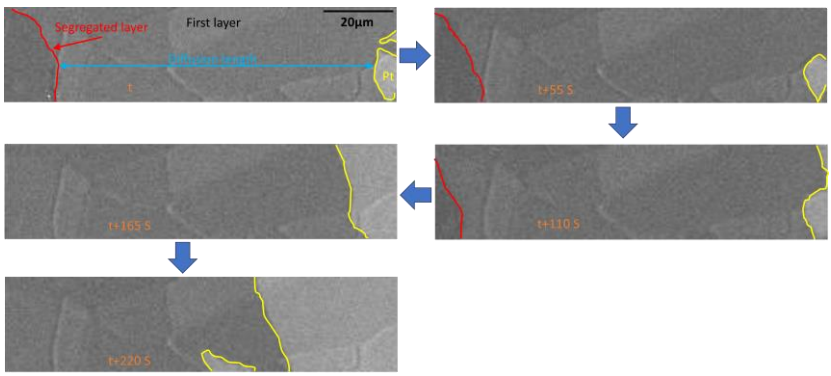

Figure 1: Snapshot of in-situ SEM H_2 etching of the first layer and the second layer (carbon segregation from the substrate)