Atomic scale imaging of 2D materials using low voltage transmission electron microscopy

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Stage pouvant se poursuivre en thèse : Oui

Résumé :

Two dimensional (2D) materials such as graphene and transition metal dichalcogenides (TMDs) show today great potential for future nanoelectronics and optoelectronics. The properties of these atomically thin layers are directly related to their atomic arrangements. Materials characterization at atomic scale is thus a critical part of the materials development. In this internship, atomic scale structural analysis of 2D materials will be performed using low-voltage aberration corrected transmission electron microscopy (LVAC-TEM). The student will develop sample preparation methods for 2D layers grown on various substrates and will participate in TEM experiments, including in-situ observation to understand the defect dynamics and phase transition triggered inside the TEM. The main task of this internship will be to optimize the use of image simulation and data processing, in order to extract structural information, such as formation and migration of defects and strain propagation, from numerous data recorded in time during in-situ experiments. This internship will be preferentially followed by a PhD work to extend the subject to atomic scale chemical and electronic analysis.

Sujet détaillé :

Graphene and new 2D materials show great potential for future nanoelectronics and optoelectronics due to their extraordinary electronic properties and structure-engineerable nature. In particular, the last several years have seen many theoretical and experimental explorations on Transition Metal Dichalcogenides (TMDs), such as MoS_2 [Columbia Univ, Phys. Rev. Lett. 105, 136805 (2010)], which attract remarkable attention in several fields of research for their enormous potential due to their semiconducting property. The properties of these atomically thin layers are directly related to their atomic arrangements. Engineering defects and strains have been demonstrated to be an interesting way to modify their local electronic properties. Moreover, the study on multi phases and phase boundaries in TMD monolayers is also an essential step towards building our understanding of the rich physics of 2D materials, which has not been fully exploited. Controlling their atomic structures can be a promising way to realize tunable opto-electronic 2D based devices. For this purpose, materials characterization is a critical part of the materials development. Low-voltage aberration corrected transmission electron microscopy (LVAC-TEM) has become one of the most powerful analytical solutions, by permitting atomic structure imaging of atomically thin 2D layers. In our laboratory, the atomic scale LVAC-TEM imaging has been intensively developed to study various 2D layers developed for nano-electronics and spintronics in CEA.

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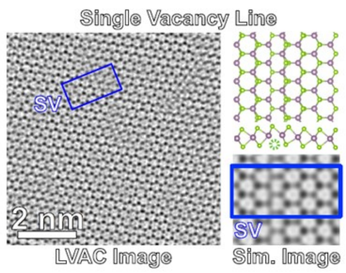
In the perspective of a PhD thesis, robust TEM techniques and new analytical methods will be developed to correlate structural, chemical and further opto-electronic properties in 2D materials. Coupling annular dark-field (ADF) STEM imaging and energy loss spectroscopy (EELS) will be exploited for a direct determination of the chemical identities and also to extract the signals related to the local electronic structure. Application of these techniques to 2D materials is still a challenge due to the weak signal and damaging samples under the convergent high energy electron beam. Finally a wide range of experimental developments will be required to achieve the objective.

The laboratory has a strong collaboration with other groups in CEA who synthesize novel 2D materials for different applications. The work will be done using state of the art low voltage microscopes in the Nano-characterization platform (PFNC) at Minatec.



Direct observation of defect (line vacancy) formation in $MoSe_2$ mono atomic layer

Compétences requises :

Condensed matter physics