Colloidal synthesis of transition metal dichalcogenides – from nano-monolayers to heterostructures.

Mahler Benoit, Shahmanesh Ashkan, Hubley Austin, Bauer Pierre, Guyot Yannick.
Institut Lumière-Matière, CNRS UMR 5306, Université Lyon 1, Université de Lyon, Villeurbanne 69622, France
benoit.mahler@univ-lyon1.fr

The past few years a tremendous attention has been given to 2D materials and in particular to Transition Metal Dichalcogenide (TMDC) compounds (MoS2, WSe2…) driven by their remarkable electronic and optical properties. TMDCs offer a compelling combination of the transport properties of graphene with the optical properties of semiconductors. As compared to other semiconductor quantum wells, pristine single layers of TMDCs -which can be as wide as several micrometers- can be obtained by a simple mechanical exfoliation from the bulk material. As a result, TMDCs have been explored as optoelectronic materials for a broad range of applications, such as photo-detection, lighting and lasing, single photon emission, nanosensing, memories…

Colloidal synthesis (CS) can offer multiple advantages over other growth methods to produce 2D nanomaterials, the most obvious one being the quantity of free-standing monolayers that can be produced at once (square meters of monolayers for a typical CS). Furthermore, this method could produce numerous nanostructure types from alloyed or doped monolayers, to in-plane and out-of-plane heterostructures. Finally, CS can give access to a size range rarely explored -forming nano-monolayers (NMLs)- where lateral confinement arises, thus becoming an additional tool to tune the optoelectronic properties of colloidal monolayers.

Based on our previous work on colloidal WS_2 monolayers synthesis,[1] we are currently developing a new strategy to synthesize colloidal TMDC NMLs with a control over their size, size dispersion, composition, crystallinity and shape. The approach consists in addressing these problems separately. A first synthetic scheme has been developed using a nucleation/growth mechanism, allowing the fabrication of monodisperse small (few nm) colloidal NMLs.[2] The size can then be tuned by continuous injection of precursors during growth. The shape can be modified using a second growth step in a different chemical environment. Finally, the crystal structure can be changed post synthetically through annealing either in solution or on a substrate. This strategy also allows for composition modifications, and has been successfully applied to produce alloyed $WSe_{2x}S_{2-2x}$ NMLs.[3]

References

[1] Mahler, B.; Hoepfner, V.; Liao, K.; Ozin, G. A., JACS, 2014, 136 (40), 14121–14127.
[2] Shahmanesh A, Hubley A, Bauer P, Guyot Y, Abecassis B, Mahler B. ChemRxiv. 2023.
[3] Shahmanesh, A. et al., J. Phys. Chem. C 2021, 125 (20), 11058–11065.

Figures

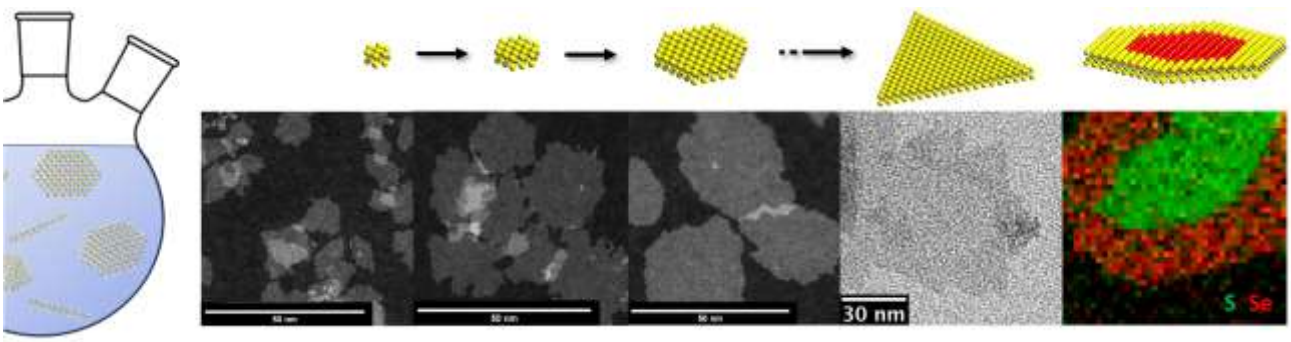

Figure 1: synthetic scheme and associated HR-STEM pictures obtained for WS_2-based NMLs.