Liquid exfoliation and defect engineering of inorganic 2D materials

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Liquid exfoliation has become an important production technique to give access to large quantities of two-dimensional nanosheets in colloidal dispersion.[1] Importantly, this is a highly versatile technique that can be applied to numerous layered materials beyond graphene such as transition metal dichalcogenides, III-VI semiconductors, black phosphorus, layered oxides to name just a few. These can be cast into films and composites and have proven useful in a number of application areas. Recent progress in size selection has enabled the production of high quality nanosheet dispersions with controlled thickness and lateral size.[2] This was made possible by spectroscopic size and thickness metrics that allow us to extract nanosheet lateral size, thickness and monolayer content from simple measurements such as extinction spectroscopy.[2,3,4]

We now use this basic understanding to systematically compare a range of 2D materials with respect to exfoliation, size selection and size-dependent properties to identify unifying principles. In all cases, we investigate chemical degradation/oxidation via the characteristic optical fingerprints.

In addition, we explore different ways for further functionalisation of TMD nanosheets by various methods (see figure 1). This includes noncovalent approaches, where we can track the functionalization in optical spectra due to the dielectric screening of the excitonic transitions. We also elaborated ways to chemically modify the basal plane [5,6] or edge sites [7] of TMDs. For example, we demonstrate that chemical functionalisation of vacancy defect sites can be used to protect otherwise instable materials from degradation while edge defects such as thiols can be converted to disulfides in redox reactions. These findings present an important step towards defect engineering in 2D materials.

References

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Figures

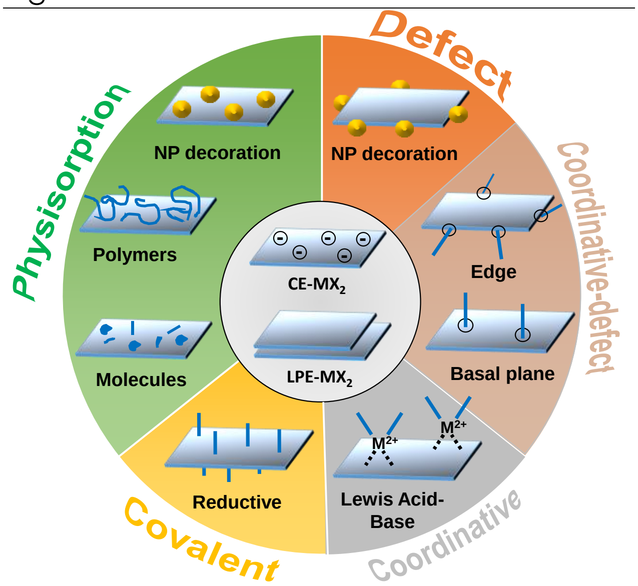

Figure 1: Functionalisation approaches for transition metal dichalcogenides in the liquid phase.