Liquid phase exfoliation, degradation and functionalisation of layered materials

Claudia Backes
Kevin Synnatschke, Sebastian Grieger, Leonhard Karger, Tim Nowack
Physical Chemistry Institute, Heidelberg University, Im Neuenheimer Feld 253, 69120 Heidelberg
backes@uni-heidelberg.de

Abstract

Liquid exfoliation has become an important production technique to give access to large quantities of two-dimensional nanosheets in colloidal dispersion. Importantly, this is a highly versatile technique that can be applied to numerous layered materials beyond graphene. In this talk, our recent advances in the liquid exfoliation, optical characterisation and degradation of a range of 2D-materials will be summarised. Materials under study include group VI TMDs, $PdSe_2$, $PtSe_2$,[1] MPS_3 (M: Ni, Mn, Fe),[2] InSe, $RuCl_3$, $CrTe_3$ and porous organic sheet stacks (2D polymers).[3] All materials can be exfoliated and size-selected in a similar way yielding nanosheet dispersions with well-defined changes in their lateral dimensions and thickness. Inherently, lateral nanosheet size and layer number are linked, in agreement with a recently developed model of energy equipartition of tearing and delamination events.[4]
The availability of a broad range of size-selected nanosheets allows us to study degradation in various environments through optical spectroscopy systematically. For materials beyond graphene, BN and transition metal dichalcogenides (TMDs), we find evidence for degradation in optical absorbance and extinction spectroscopy that allow us to track degradation kinetics. In the case of group VI-TMDs, we use photoluminescence measurements as function of time and temperature in dispersion to selectively track monolayers. Depending on the surfactant used as stabilizers, monolayers of WS_2 react in ambient conditions in a photo-induced, as well as thermal degradation pathway with activation energies of ~25-30 kJ/mol and ~50 kJ/mol, respectively.[5] This confirms the recently observed difference in nanosheet reactivity depending on the surfactant coverage.[6] Finally, we present our attempts to passivate reactive defects through functionalisation.

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