

## Covalent functionalization of photoluminescent liquid-exfoliated WS<sub>2</sub> nanosheets

**Tim Nowack**<sup>1,2</sup>, Steffen Ott<sup>2</sup>, Andreas Mischok<sup>3</sup>, Wen-Shan Zhang<sup>4</sup>,  
Rasmus R Schröder<sup>4</sup>, Malte Gather<sup>3</sup> and Claudia Backes<sup>1,2</sup>

<sup>1</sup> University of Kassel, Physical Chemistry of Nanomaterials, Heinrich-Plett-Str. 40,  
D-34132 Kassel

<sup>2</sup> University of Heidelberg, Institute of Physical Chemistry, D-69120 Heidelberg

<sup>3</sup> University of Cologne, Humboldt Centre for Nano- and Biophotonics, Greinstr. 4-6,  
D-50939 Cologne

<sup>4</sup> University of Heidelberg, Centre for Advanced Materials, Im Neuenheimer Feld 225, D-69120,  
Heidelberg

Tim.Nowack@uni-kassel.de

Transition metal dichalcogenides (TMDs), such as WS<sub>2</sub>, turn from indirect into direct semiconductors when exfoliated to monolayer thickness. For applications in (opto-)electronics, enhancement of the intrinsically low photoluminescence quantum yield of TMD nanosheets would be required. One potential approach to tackle this task, is the introduction of new types of defects to the nanosheet surface. In this project the covalent aryl functionalization of liquid-phase exfoliated WS<sub>2</sub> nanosheets (f-WS<sub>2</sub>) and effects upon optical properties were investigated. Since first results pointed towards an improved nanosheet-nanosheet separation in thin films from functionalized monolayer-enriched dispersions, the material was embedded in cavities and reflectivity experiments were performed, to learn whether strong-coupling can be achieved from our largely liquid-based processing protocols. Liquid-phase exfoliated WS<sub>2</sub> nanosheets in water/surfactant dispersions were size selected, according to literature known centrifugation protocols.<sup>[1]</sup> Dispersions with high monolayer content were treated with aryl diazonium salts in different concentrations to achieve functionalization. By performing solvent transfer to IPA, colloidal stable dispersions were obtained, which were used for further film fabrication. Extinction, Raman and photoluminescence (PL) spectroscopy suggest reduced nanosheet aggregation due to functionalization. In thin films spectral features typical of individual TMD monolayers, such as A exciton PL, are largely maintained. Characterization of films, assembled at liquid-liquid interfaces and deposited via a Langmuir based method, suggests that functionalization leads to improved high film homogeneities and increased hydrophobicity of surfaces. Such films embedded in cavities allow for the detection of exciton-polaritons, which might represent a further step towards polaritonic devices from liquid-phase processed TMDs.

### References

- [1] Backes et al., ACS Nano, 10, 1589-1601 (2016).