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Nanocrystal deposition of 2D-transition metal trihalide solid solutions by chemical vapor transport

Samuel Froeschke, Karl-Georg Schroth, Rico Fucke, Nadia Yasmen, Bernd Büchner, Peer Schmidt, Silke Hampel
Leibniz Institute for Solid State and Materials Research, Helmholtzstraße 20, Dresden, Germany
s.froeschke@ifw-dresden.de

The search for new 2D materials with exceptional properties has not slowed down even almost 20 year after the discovery of graphene. The development of solid solutions of established 2D materials has gained more and more interest in recent years [1], as it opens up great possibilities to optimize certain material properties or to discover completely new ones. In this regard the class of transition metal trihalides offers a wide playground of possible solid solution combinations since a lot of these compounds already offer a 2D crystal structure, as seen in figure 1a. [2] In this presentation we demonstrate the synthesis of $CrCl_3$-$RuCl_3$ solid solutions as an example of this material class with the focus on a bottom-up approach for the deposition of nanocrystals directly on a substrate. By optimizing our chemical vapor transport method, we are able to obtain nanosheets with high crystallinity of about 30 nm in height and several µm in lateral size. By applying a consecutive delamination step with a short ultrasonication step we are able to uncover fewlayer and even monolayer structures directly on the substrate. These structures were investigated by Raman-spectroscopy and transmission electron spectroscopy and can also be used for further research on possible downscaling effects. We show detailed results for $CrCl_3$-$RuCl_3$ solid solutions with an outlook for further solid solutions of $CrCl_3$-$CrBr_3$-CrI_3, $CrCl_3$-$MoCl_3$ or $RhCl_3$-$RhBr_3$, which are also accessible by the presented method.

References

[1] W. Hong, B. C. Wyatt, S. K. Nemani, B. Anasori, MRS Bulletin, 45 (2020) 850-861
[2] M. A. McGuire, Crystals, 7 (2017) 121

Figures

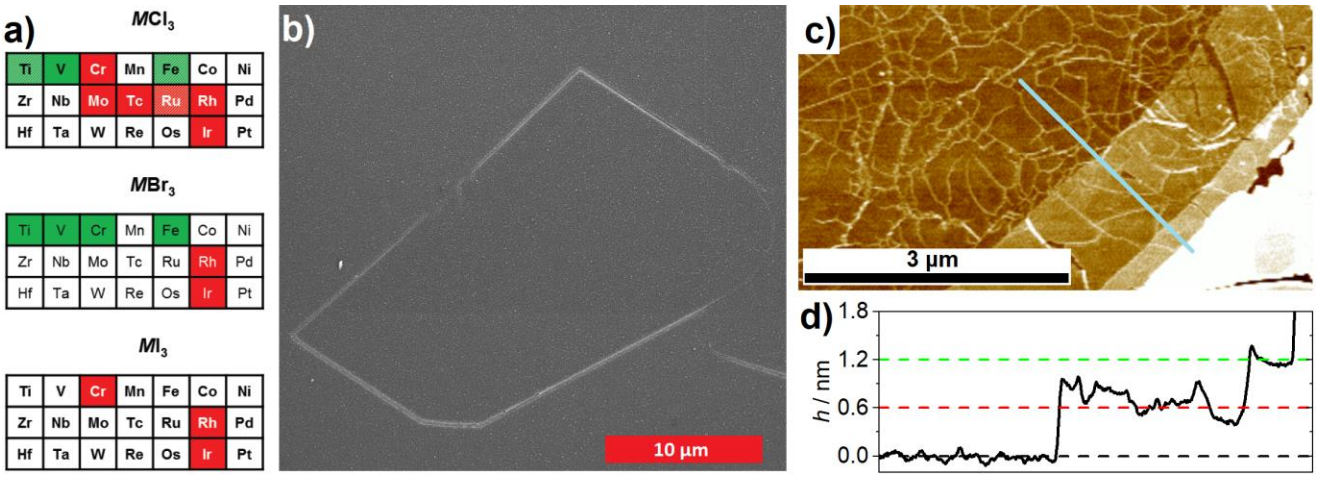

Figure 1: a) overview of transition metal trihalides with 2D structure (red: $AlCl_3$-type, green: BiI_3-type) [1], b) SEM image of an as grown $Cr_xRu_{1-x}Cl_3$ nanocrystal with a height of ca. 30 nm (surface particles and cracks can be attributed to carbon sputtering), c) AFM image of a $Cr_xRu_{1-x}Cl_3$ fewlayer structure obtained by delamination, d) height profile of the in c) shown step of a mono- and bilayer.