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New Inorganic Materials through Selective Reactivity of Solids

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In addition to synthesis from elements or binaries, new inorganic compounds and materials can also be obtained by targeted modification of complex solids under moderate conditions that preserve a close structural relationship between the starting material and the product. The product of such a topochemical reaction can have a different composition or/and morphology and dimensionality. Of course, this changes the chemical and physical properties of the material [1-3]. For a topochemical reaction, the starting material should exhibit significant internal contrast of chemical bonding, either in terms of strength or type. Topochemical reactions are by no means only of academic interest, as the example of battery or absorber materials show. Typically, the solid reacts with a liquid or gaseous phase in a heterogeneous reaction in which mass transfer occurs through the solid. The (diffusion) kinetics, which are often slow, cannot be accelerated by an arbitrary increase in temperature, as this would also impair the selectivity of the reaction. Instead, additional mechanical or electrical driving forces or auxiliary agents can be used.

We developed such reactions to create low-dimensional functional materials, e.g., nanoflakes of topological insulators [4,5]. 2D materials are usually composed of few layers and have a large aspect ratio. They are to be used, e.g., in electronic and optoelectronic devices, in spintronics, or in biomedical and environmental sensors. Beyond widely researched materials such as graphene, transition metal dichalcogenides and MXenes, we have selected unusual and chemically challenging systems. These include layered salts, where a strong electrostatic attraction must be overcome during chemical exfoliation [4], but also starting materials that are highly sensitive to hydrolysis and therefore tend to decompose as a whole [6].

In addition to controlling the chemical reaction, the structural characterization and further handling of the nanoscale products also poses a challenge. In combination with standard electron microscopy and scanning probe techniques, we have used 3D electron diffraction tomography to solve even complex crystallographic problems on intergrown and twinned nanoplatelets [6]. For the production of dense 2D particle layers of quantum materials, we have developed a microfluidic system that enables continuous exfoliation and combined it with liquid phase deposition techniques.

[1] M. Kaiser et al., *Angew. Chem. Int. Ed.* **2014**, *53*, 3254. [2] M. Heise et al., *Angew. Chem. Int. Ed.* **2014**, *53*, 7344. [3] T. Herrmannsdörfer et al., *Phys. Rev. B* **2011**, *83*, 140501. [4] M. Lê Anh et al., *Chem. Eur. J.* **2021**, *27*, 794. [5] M. Lê Anh et al., *npj 2D Mater. Appl.* **2021**, *5*, 22. [6] W. Carrillo-Cabrera et al., *Inorg. Chem.* **2024**, DOI: 10.1021/acs.inorg chem.4c01674.

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