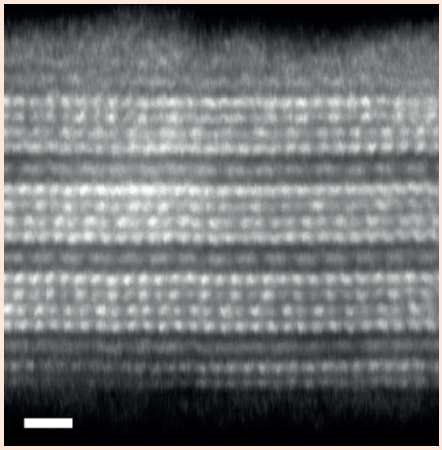
VAN DER WAALS HETEROSTRUCTURES

The natural way

Franckeite is a naturally occurring mineral discovered in Bolivia at the end of the eighteenth century. It belongs to the sulfosalt family and is composed of an alternating sequence of weakly bound, incommensurately stacked PbS and SnS_2 layers separated by van der Waals gaps. The strong compositional segregation for Pb and Sn atoms leads to markedly different electronic band structures for the different layers, whose overall properties may be further complicated by Pb/Sb and Sn/Fe partial substitutions.

Now, writing in *Nature Communications*, two independent research groups report the exfoliation of franckeite into few-layer-thick heterostructures that can be thought of as natural counterparts of an artificial van der Waals heterostructure. Both A. J. Molina-Mendoza *et al.* (*Nat. Commun.* **8,** 14409; 2017) and M. Velický *et al.* (*Nat. Commun.* **8,** 14410; 2017) exploit mechanical and liquid-phase exfoliation processes to obtain ultrathin nanoflakes. The cross-section of a typical sample is shown (from the study of Velický *et al.*; scale bar, 1 nm), visualized by means of high-angle annular dark-field scanning transmission electron microscopy. Remarkably, Velický *et al.* even succeed in exfoliating single-unit-cell-thick heterostructures.



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In comparison with their artificial analogues, franckeite-based van der Waals heterostructures show advantageous properties because the mutual orientation of the different layers is preserved across the nanoflakes and, simultaneously, the occurrences of spurious interlayer adsorbates are kept at a minimal level. Also, the franckeite nanoflakes are stable even after exposure to air for several months — even though Velický *et al.* observe a marked degradation of the thinnest samples and, in general, surface deterioration effects. This stability is reflected in the preservation of the p-type, narrow-bandgap semiconducting behaviour also observed for the bulk material, as confirmed by means of transport measurements in back-gated devices and by scanning tunnelling spectroscopy. This behaviour is in stark contrast to phosphorene, also a two-dimensional p-type, narrow-gap semiconductor possessing comparable electronic properties — yet, not air-stable.

The two groups also demonstrate possible technological applications for the considered nanoflakes. Molina-Mendoza *et al.* focus on the moderate bandgap values (~0.7 eV) to investigate the potential of few-layer franckeite as a near-infrared photodetector. Moreover, exploiting the p-type semiconducting character, they fabricate proof-of-principle p–n photodiodes made of few-layer franckeite and n-doped few-layer MoS_2. Velický *et al.* focus instead on the electrochemical properties of exfoliated franckeite samples and, in particular, show good electric double-layer capacitance and high electron-transfer rate values. These aspects suggest the possible exploitation of few-layer franckeite for applications in energy-storage and conversion applications.

GIACOMO PRANDO

NANOMEDICINE

Catching tumour cells in the zone

A microfluidic chip with progressively stronger magnetic field gradients along its length can sort and classify circulating tumour cells based on the expression of cell surface markers.

Susan E. Leggett and Ian Y. Wong

Circulating tumour cells (CTCs) disseminating through the bloodstream represent a missing link between the initiating tumour and its metastatic colonies[1]. The isolation and analysis of CTCs from patient blood samples could enable noninvasive 'liquid biopsies' for the early detection, diagnosis and prognosis of cancer[2]. However, CTCs are highly heterogeneous and extremely rare (1–10 CTCs per billion blood cells), making them difficult to detect and isolate. CTCs have been separated using size-based filtration or other microfluidic techniques as they tend to be larger than blood cells[3]. Nevertheless, these physical approaches may overlook some subset of CTCs that are comparable in size to blood cells. Alternatively, CTCs may be labelled or captured using antibody-conjugated magnetic nanoparticles, which can be highly effective since unlabelled cells exhibit minimal magnetic susceptibility. Recently, Ozkumur *et al.* used a magnetic field gradient to deflect magnetically labelled CTCs from an inertially focused stream of cells[4]. Issadore *et al.* interrogated magnetically labelled CTCs using miniaturized Hall-effect sensors, which transduce magnetic fields into a change in output voltage[5]. Together, these approaches have primarily been used to either enrich or detect CTCs.