Phase engineering of 2D materials

Available Technologies

A Step-Change in the Phase-Engineering of Layered Semiconductors

2D materials have many unique properties such as high surface area, exceptional mechanical strength, and excellent electrical and thermal conductivity.

Transition metal dichalcogenides (TMDs) e.g. molybdenum disulfide, are a class of 2D materials whose metallic 2D forms are ideal candidates for next-generation device applications such as field effect transistors or hydrogen evolution reaction catalysts. Along with their 2D applications, exfoliated bulk TMDs are useful in lubricants, composites, and batteries.

In their pure form, TMDs are semiconductors, and to-date, the chemical phase transformation from the semiconducting (2H) to metallic (1T) phase in is almost exclusively based on chemical lithiation using an air sensitive and pyrophoric potentially explosive substance n-BuLi. This process takes several days, requires high temperatures and dangerous chemicals, with the lack of alternative options, it has remained the dominant process since 1975.

The inventors of this process have identified a route to achieve the phase transition using safer chemicals, lower temperatures and which is orders of magnitude faster than the conventional approach creating a milder, safer, greener, higher-yielding reaction. Not only is the process extremely effective at making alkali-metal intercalated structure for exfoliating and converting phase of bulk TMDs, but its associated kinetics allows for resist-free phase patterning of mono, or few-layered semiconductors.

Technology overview

- The invention is a method for converting semi-conducting (2H) TMDs to the (1T/1T') conducting phase
- So far, this method has been demonstrated on group 6 layered TMDs including sulphides, selenides and tellurides
- The method is capable of converting TMDs in a range of physical forms; from bulk, granulated, powdered, monolayers, bilayers, or multilayers
- Along with the phase transfer, this method promotes the delamination and dispersion of bulk TMDs into an aqueous solution
- The method promotes a shift away from pyrophoric n-BuLi, and instead the reducing agent can include an intercalating metal from group 1 or group 2 from an aromatic organometallic

Benefits

- Rapid reaction for cation intercalation and phase engineering
- Safer chemicals
- Ambient temperatures and pressure
- Ability to phase pattern using low cost, scalable methods.

Applications

This process exhibits promising applications in the development of materials for the following domains:

- Batteries
- Next generation electronics

- Lubricants
- Composites

Opportunity

We are seeking industrial partners to help to commercialise the technology under license.

Inventors

Professor Akshay Rao

Akshay is Professor of Physics at the Cavendish Laboratory, University of Cambridge. He obtained BSc from St Stephen's College, University of Delhi, in 2006 and MSc from the University of Sheffield in 2007. He completed his Ph.D. from the University of Cambridge in 2011, following which he held a Junior Research Fellowship (JRF) at Corpus Christi College, before establishing his independent research group in 2015. He was awarded the Henry Moseley Medal and Prize of the Institute of Physics for "exceptional early career contributions to experimental physics" and has also been awarded an EPSRC Early Career Fellowship and ERC grants. He is the co-founder of Cambridge Photon Technology and Illumion.

Dr Christoph Schnedermann

Christoph is CTO of illumion Ltd., a spin out company from the University of Cambridge. He received his PhD in Physical Chemistry from the University of Oxford, completed a post-doc at Harvard University and is currently an Entrepreneurial Fellow of the Faraday Institution at the University of Cambridge.

Juhwan Lim

Juhwan is a PhD candidate in the Department of Physics at the University of Cambridge. His research interests are in optoelectronic and energy devices based on two-dimensional semiconducting materials.

Patent

UK Patent Office Application 2312904.2