
Piezoelectric Tin-monosulfide Candidates for Developing Flexible Nanogenerators

2020-08-03

An RMIT-UNSW collaboration has applied liquid-metal synthesis to piezoelectrics, advancing future flexible, wearable electronics, and biosensors drawing their power from the body's movements.

Materials such as atomically-thin tin-monosulfide (SnS) are predicted to exhibit strong piezoelectric properties, converting mechanical forces or movement into electrical energy.

This property, along with their inherent flexibility, makes them likely candidates for developing flexible nanogenerators that could be used in wearable electronics or internal, self-powered biosensors.

However to date, this potential has been held back by limitations in synthesising large, highly crystalline monolayer tin-monosulfide (and other group IV monochalcogenides), with difficulties caused by strong interlayer coupling. The new study resolves this issue by applying a new liquid-metal technique, developed at RMIT, to synthesise the materials.

Subsequent measurements confirm that tin-monosulfide synthesised using the new method displays excellent electronic and piezoelectric properties. The resulting stable, flexible monolayer tin-monosulfide can be incorporated in a variety of devices for efficient energy harvesting.



Output voltage in a practical, wearable device: voltage output during tensile bending and relaxing (two-electrode device).

The work started over two and a half years ago and strong collaborative work between RMIT

and UNSW allowed its fruition. Ms Hareem Khan, the first author of the paper, showed remarkable perseverance to surmount many technical challenges to demonstrate the viability of the concept, with Prof Yongxiang Li.

Liquid metal synthesis

The unprecedented technique of synthesis used involves the van der Waals exfoliation of a tin sulphide (SnS), that is formed on the surface of tin when it is melted, while being exposed to the ambient of hydrogen sulfide (H₂S) gas. H₂S breaks down on the interface and sulfurises the surface of the melt to form SnS.

The technique is equally applicable to other monolayer group IV monochalcogenide, which are predicted to exhibit the same strong piezoelectricity. This liquid metal based method allows us to extract homogenous and large scale monolayers of SnS with minimal grain boundaries.



Synthesis process: an atomically-thin layer of tin-sulfide is applied onto a flexible nanogenerator transducer.

Measurements confirm the material has high carrier mobility and piezoelectric coefficient, which translates into exceptional peak values of generated voltage and loading power for a particular applied strain, impressively higher than that any previously reported 2D nanogenerator.

High durability and flexibility of the devices are also demonstrated. This is evidence that the very stable as-synthesised monolayer SnS can be commercially implemented into power-generating nanodevices.



Transmission electron microscope (TEM) image: atomically thin (monolayer) tin-sulfide nanosheet (scale

bar is 500 nm).

They can also be used for developing transducers for harvesting mechanical human movements, in accordance to the current technological inclinations towards smart, portable and flexible electronics.

The results are a step towards piezoelectric-based, flexible, wearable energy-scavenging devices. It also presents an unprecedented synthesis technique for large (wafer) scale tin-monosulfide monolayers.

Piezoelectric materials

Piezoelectric materials can convert applied mechanical force or strain into electrical energy. Best known by name in the simple 'piezo' lighter used for gas BBQs and stovetops, piezoelectric devices sensing sudden changes in acceleration are used to trigger vehicle air bags, and more-sensitive devices recognise orientation changes in mobile phones, or form the basis of sound and pressure sensors.



Two-electrode device (left, with scale bar 1 mm), and response of output voltage using tapping mode (right, with scale bar 50 μm).

Even more sensitive piezoelectric materials can take advantage of the small voltages generated by extremely small mechanical displacement, vibration, bending or stretching to power miniaturised devices, for example biosensors embedded in the human body, removing the need for an external power source.

The study, "Liquid metal-based synthesis of high performance monolayer SnS piezoelectric nanogenerators," was published in [Nature Communications](#) in July 2020.

Read the [original article](#) on Future Low-Energy Electronics Technologies (or FLEET).