interface is not seen in a tri-phase nanoparticle, it will not occur in higher order nanoparticles.

“Our work will be a fundamental driver for designing novel polyelemental nanoparticles for many applications,” Mirkin told *Nano Today*. “Eventually, polyelemental nanoparticles with optimized interface structures may have applications spanning catalysis, plasmonics, nanoelectronics, and energy harvesting.”

The team’s approach could help find just the right nanoparticle for a particular application as so many different combinations of particle size, composition, and position can be generated.

“If SPBCL is combined with a massively parallel patterning technique such as polymer pen lithography (PPL), millions of probes over centimeter-scale areas could be used to generate millions of different polymer nanoreactors simultaneously,” he explains. “This provides a powerful platform for nanocombinatorics, where new nanoparticle compositions, including those that are not easily accessible by conventional techniques, can be generated, characterized, and screened.”

Luis M. Liz-Marzán, scientific director of CIC biomaGUNE in Spain, believes that the work shows just what rational engineering of the distribution of different metals in a nanoparticle can achieve.

“By taking a combinatorial approach to particle design, together with annealing, the elemental distribution and strain can be engineered, which may have large relevance in various fields and in catalysis in particular,” he says Alexander Govorov of the University of Ohio agrees that the work makes an important contribution to the field of multi-component nanocrystals. “The importance of the dimension of a nanoparticle is well known since the surface-to-volume ratio is one of the key parameters of catalysis,” he points out. “But this work brings another parameter, which could potentially lead to more efficient catalysis and photocatalysis: multi-component structure with interfaces transparent for charge transfer.”

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1748-0132/$ — see front matter
https://doi.org/10.1016/j.nantod.2019.04.001

Transition metal nanobelts show high conductivity

Cordelia Sealy

Two-dimensional materials usually boast high carrier mobility when the carrier density is low. But now researchers have fabricated nanobelts of the transition metal NbAs that show high mobility even when the carrier density is also high [Zhang et al., *Nature Materials* (2019), https://doi.org/10.1038/s41563-019-0320-9].

If conventional bulk metals are reduced to the nanoscale, conductivity decreases because surface roughness and defects scatter the charge carriers, reducing their overall mobility. Recently, however, a new type of topological materials called Weyl semimetals have been discovered. In single crystals of these exotic materials, the conduction and valence bands touch at specific points leading to unusual electronic properties and phenomena.

Now a team from Fudan University, the High Magnetic Field Laboratory of the Chinese Academy of Sciences in Heifei, Nanjing University of Science and Technology, Beijing University of Technology, the University of Queensland, Brisbane, ETH Zurich, Trinity College Dublin, and University of California, Davis has designed a new way of synthesizing the Weyl semimetal NbAs. Their approach is based on chemical vapor deposition, taking advantage of the reaction between the metal chloride $NbCl_5$ with hydrogen at high temperatures and low pressures. When carried out in an As atmosphere with a thin (15 nm) Au layer acting as a catalyst, nanobelts of NbAs are produced.

The NbAs nanobelts are highly crystalline, with a large proportion of (001) surfaces, and can be regarded as a three-dimensional

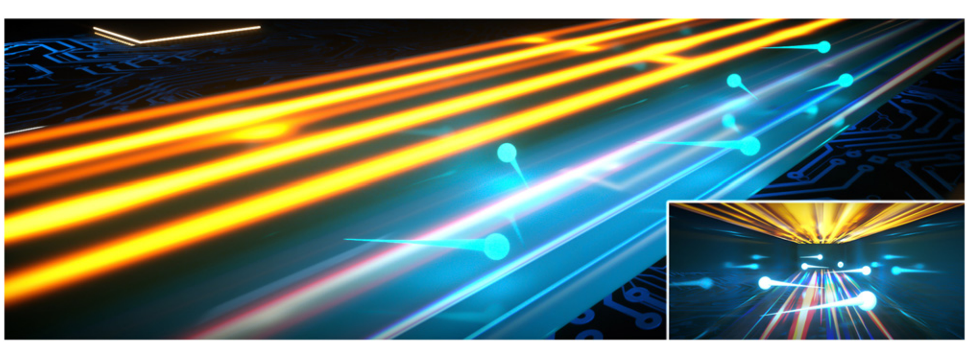

Fig. 1. Sketch of ultrahigh conductivity in NbAs nanobelts. The surface state of NbAs nanobelts is found to host the largest sheet conductivity. The electrons are mostly transported through surface states without encountering large-angle scattering.

version of graphene with specific chirality, explains Faxian Xiu of Fudan University, who led the research.

"We found that the surface states of NbAs nanobelts present the highest sheet conductivity among all two-dimensional systems," he says.

The team's exploration of the electrical properties of the NbAs nanobelts reveals that they are metallic, with resistivity more than an order of magnitude lower than the bulk material. Moreover, the room temperature conductivity of NbAs nanobelts is comparable to conventional metallic conductors like Cu, Au, and Ag. These unusual properties can be put down to the unique band structure of these nanobelts, where surface states form an arc-like structure that allows the movement of charge carriers with greatly reduced scattering rates, resulting in high conductivity (Fig. 1).

"Both the mobility and carrier density values in the surface of NbAs nanobelts can achieve high values, unlike other systems in which high carrier density limits the mobility," points out Xiu. "This unique property comes from the low-scattering-rate nature of Fermi arcs, which form the surface electronic structure in NbAs."

The ability of Weyl semimetals such as NbAs to apparently overcome the traditional tradeoff between carrier density and mobility could open up the way to highly conductive two-dimensional materials.

"[This approach] could be utilized to design proper interconnect materials that link together millions of transistors inside chips," points out Xiu. "NbAs nanobelts may also have potential prospects in thermoelectric conversion and supercapacitors, where high conductivity is in demand."

The team now plans to study the thermal and thermoelectric transport properties of NbAs nanobelts to unravel the carrier dynamics of this unusual system further.

Cordelia Sealy has many years' experience as a scientific journalist and editor in areas spanning nanotechnology, materials science and engineering, physics and chemistry. She has served as Editor of *Materials Today* and *Nano Today*, and more latterly as Managing Editor of both titles. She has also worked in academic publishing as a books acquisitions editor and in business-to-business publishing as a journalist on *European Semiconductor*. She has a First in Physical Sciences (BSc) from University College London and a DPhil in materials science from the University of Oxford, and is a Member of the Institute of Physics. Cordelia is currently a freelance science writer for her own company, Oxford Science Writing, and News and Opinions Editor for *Nano Today*.

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1748-0132/$ — see front matter
https://doi.org/10.1016/j.nantod.2019.04.004