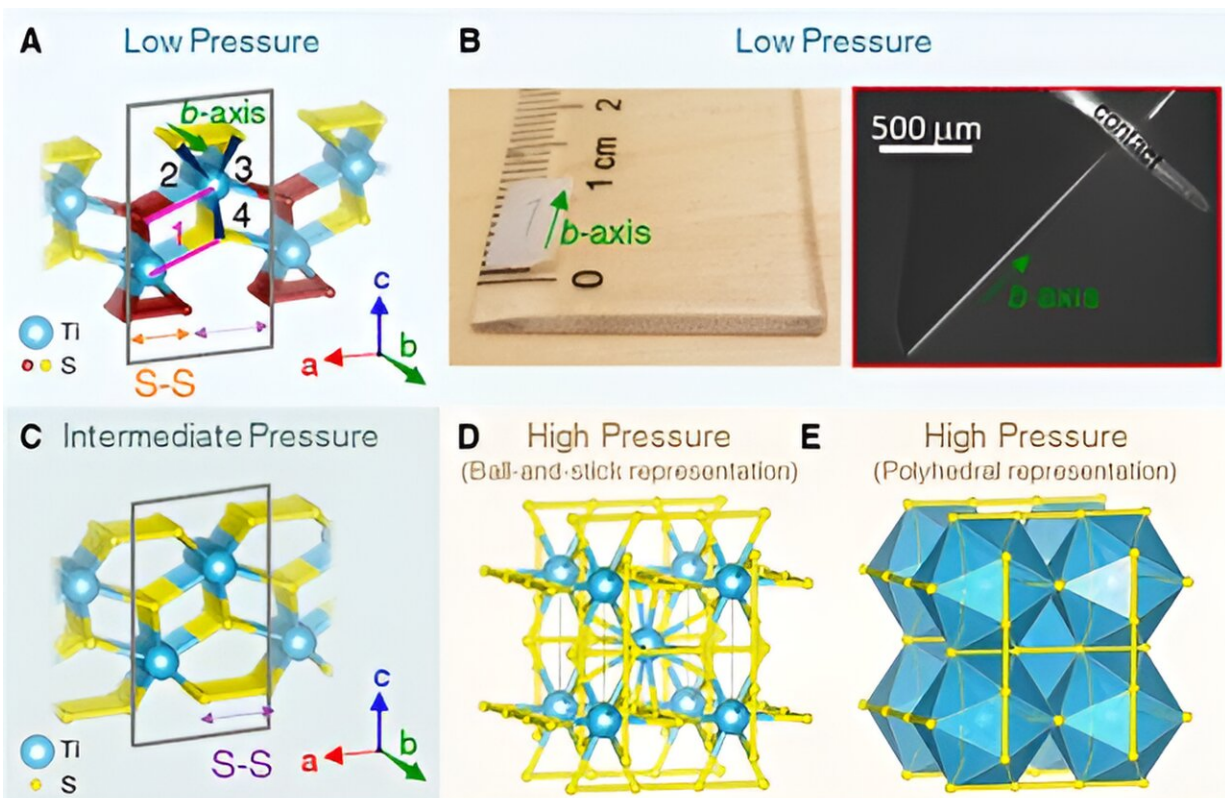


Compressed titanium and sulfur nanoribbons can transmit electricity without energy loss, scientists find

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Pressure-induced phases of TiS_3 . (A) Monoclinic crystal lattice of TiS_3 (space group of $P2_1/m$ (type-I)) at low pressure. The gray box outlines the periodic unit cell. Bond 1 (magenta) is 2.67 Å long, while the bonds 2, 3, and 4 (dark blue) are

2.49 Å long on average. To show clearly the embedded 1D chains, we use maroon and yellow S atoms to differentiate the two different (but equivalent) chains within a periodic unit cell. The S–S pair (labeled in orange) connects S atoms attached to the same Ti. (B) Left: A photograph of a Q1D TiS_3 microstructure (seen as a dark line) on a white paper. Right: SEM image of the TiS_3 whisker at low pressure. (C) Monoclinic crystal lattice of TiS_3 , $P2_1/m$ (type-II), at intermediate pressure. The gray box outlines the periodic unit cell. The S–S bond (labeled in purple) connects S atoms attached to different Ti. (D) Cubic crystal lattice of the high-pressure phase (space group of $Pm\bar{3}m$) in the ball-and-stick representation. (E) Cubic crystal lattice in the polyhedral representations. Credit: *Nano Letters* (2024). 10.1021/acs.nanolett.4c00824

When compressed, nanoribbons of titanium and sulfur can change properties dramatically, turning into materials with the ability to conduct electricity without losing energy, according to a study published in the journal [*Nano Letters*](#).

The authors have made the discovery during their painstaking search for new [materials](#) that can transmit [electricity](#) without loss of [energy](#), a hot topic that has for long haunted the scientific community.

"Our research focuses on one such promising material: TiS_3 nanoribbons, which are tiny, ribbon-like structures made of titanium and sulfur. In their natural state, TiS_3 nanoribbons act as insulators, meaning they do not conduct electricity well," says Mahmoud Rabie Abdel-Hafez, an associate professor at University of Sharjah's Department of Applied Physics and Astronomy.

"However, we discovered that by applying [pressure](#) to these nanoribbons, we could change their electrical properties dramatically," adds Abdel-

Hafez, who is the study's main author.

The scientists exposed TiS_3 to gradual pressure. As they increased the pressure, they found that the TiS_3 system underwent a series of transitions, from being insulators to becoming metals and superconductors, for the first time.

TiS_3 materials are known to work as good insulators, but it is the first time scientists have discovered that under pressure they can function as superconductors, paving the way for the development of superconducting materials.

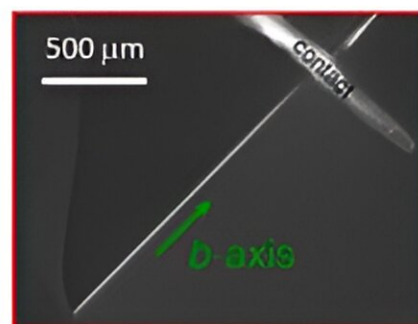
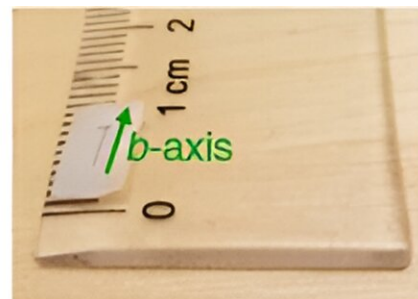
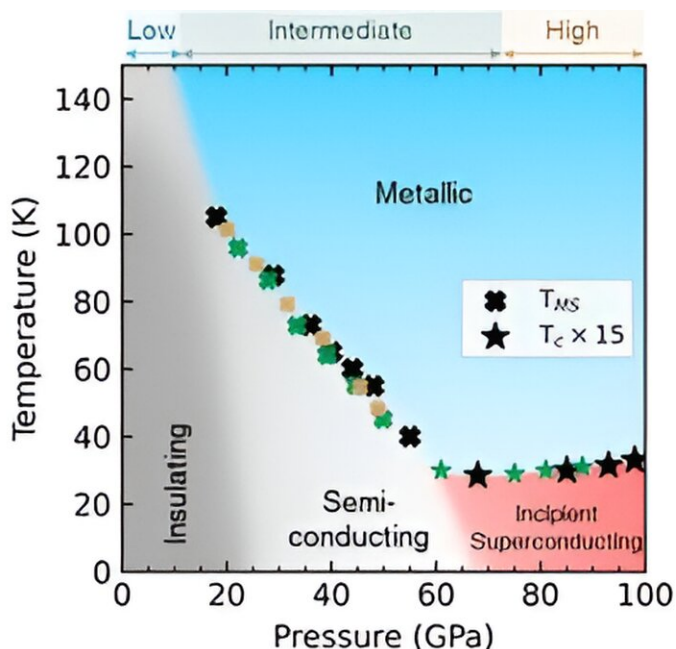
"Superconductors are special because they can conduct electricity with zero energy loss, which is incredibly valuable for technological applications," says Abdel-Hafez. "[But] imagine a world where [electrical power](#) could be transmitted without any energy being wasted as heat. This would revolutionize how we use and distribute electricity, making everything from power grids to [electronic devices](#) far more efficient."

It is exactly this potential which the authors tout as a breakthrough: the potential of TiS_3 to turn into materials causing no waste when transmitting electricity. By carefully controlling the pressure applied to these materials, the authors identified the exact points where they changed from one state to another.

"This is significant because understanding these transitions helps us learn how to manipulate other materials in similar ways, bringing us closer to discovering or designing new superconductors that can operate at higher temperatures and more practical conditions," notes Abdel-Hafez .

The study shows that TiS_3 has the potential to become such a material when subjected to the right conditions. By gradually increasing the pressure on the investigated materials, the authors observed that they

transitioned from being insulators (poor conductors) to metals (good conductors) and finally to superconductors (perfect conductors with no energy loss).



(A) Temperature-pressure phase diagram of TiS_3 . (B) Photograph and SEM image of quasi-1D microstructure. Credit: *Nano Letters* (2024).
10.1021/acs.nanolett.4c00824

Discovering that TiS_3 materials can become superconductors under pressure is certain to help scientists understand more about the conditions required for superconductivity. This knowledge is crucial for developing new materials that might be superconductors at higher, more practical temperatures, the authors maintain.

"This research not only enhances our understanding of superconductivity but also demonstrates the power of international collaboration in

achieving groundbreaking scientific results," affirms Sweden's Uppsala University Professor of Physics and Astronomy, a co-author.

The project is part of University of Sharjah's research quest to develop materials that can transmit electricity without energy loss, offering new insights into how pressure can transform the electrical properties of TiS_3 nanoribbons.

The study is a joint endeavor in which scientists from Sweden, China and Russia took part. "This advancement not only pushes the boundaries of material science but also holds the promise of groundbreaking applications in various fields, including energy transmission and electronic devices," says Abdel-Hafez.

On the method adopted to conduct the study, the authors write that they pursued "experimental and theoretical approaches to comprehensively explore the high-pressure behavior of the electronic properties of TiS_3 , a quasi-one-dimensional (Q1D) semiconductor, across various temperature ranges.

"Through high-pressure [electrical resistance](#) and magnetic measurements at elevated pressures, we uncover a distinctive sequence of phase transitions within TiS_3 , encompassing a transformation from an insulating state at ambient pressure to the emergence of an incipient superconducting state above 70 GPa."

According to Abdel-Hafez, the study paves the way for finding new superconductors, a hunt which he likened to "the search for the holy grail in materials science because these materials can conduct electricity without any energy loss. This is crucial as it could lead to incredibly efficient power transmission and numerous technological advancements."

However, the authors note more research is needed to understand how these superconductors work and the theories behind them, topics which are still hotly debated in the literature. "In our research paper on TiS_3 materials, we found that we could change their electrical properties dramatically.

"These materials have the potential to revolutionize power transmission by enabling electricity to be conducted without any energy loss. Additionally, they could advance technologies in medical imaging, electronic devices, and transportation systems such as maglev trains," says Abdel-Hafez.

The authors are upbeat about the implications of their findings. They note, "Our findings provide compelling evidence that superconductivity at low temperatures of ~ 2.9 K is a fundamental characteristic of TiS_3 , shedding new light on the intriguing high-pressure electronic properties of TiS_3 ."

More information: Mahmoud Abdel-Hafiez et al, From Insulator to Superconductor: A Series of Pressure-Driven Transitions in Quasi-One-Dimensional TiS_3 Nanoribbons, *Nano Letters* (2024). [DOI: 10.1021/acs.nanolett.4c00824](https://doi.org/10.1021/acs.nanolett.4c00824)

Provided by University of Sharjah

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