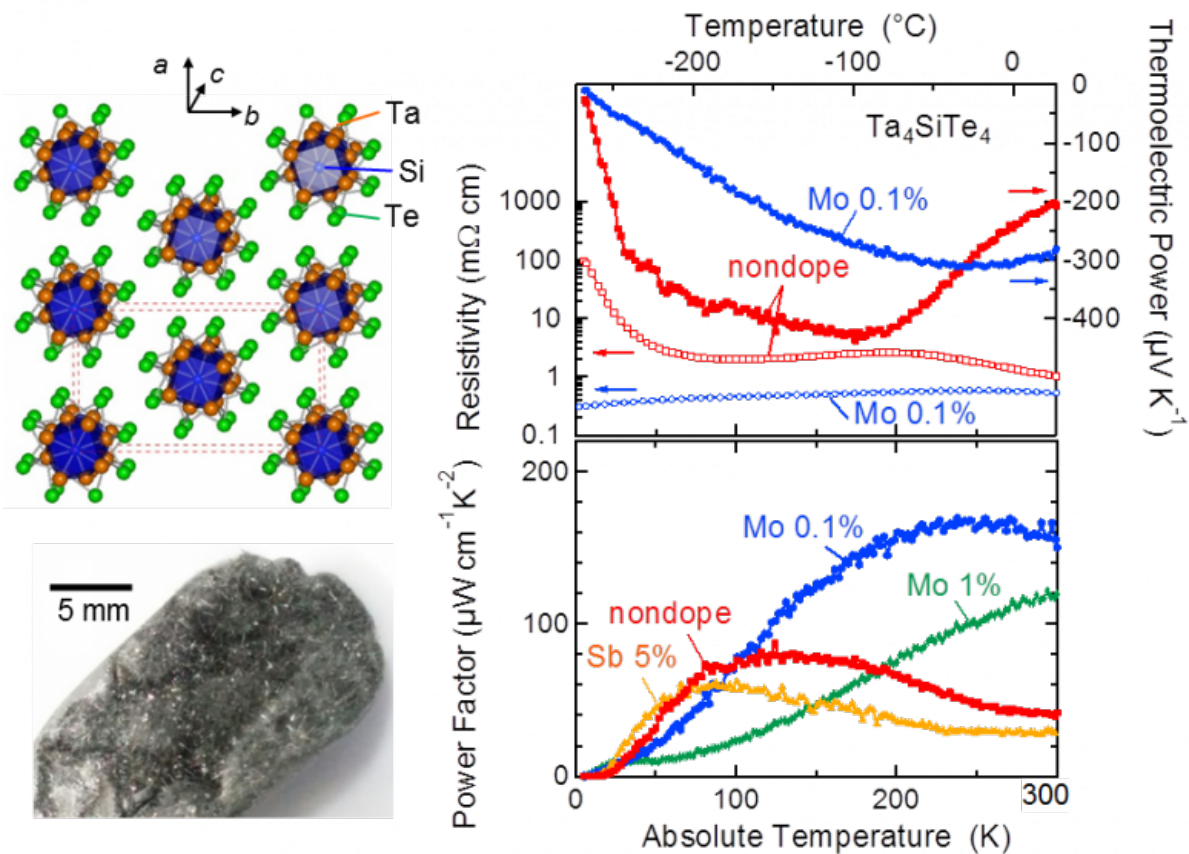


One-dimensional crystals for low-temperature thermoelectric cooling

May 24 2017



Ta₄SiTe₄ whisker crystals (left lower) show very large thermoelectric power exceeding $-400 \mu\text{V K}^{-1}$ at low temperature, while maintaining low electrical resistivity (right upper). This results in that thermoelectric power factor (right lower), an indication of cooling power, becomes a very large value far exceeding those of the practical materials (typically $40 \mu\text{W cm}^{-1} \text{K}^{-2}$ for the Bi₂Te₃-based material). The optimum temperature of the power factor can be widely

controlled by molybdenum (Mo) or antimony (Sb) doping. Credit: Nagoya University

Thermoelectric cooling is a solid-state refrigeration process where the heat in an electrically conductive material is transferred using the material's own conduction electrons without any need for the gaseous coolants, such as chlorofluorocarbons, that are used in conventional refrigeration. Coolers based on thermoelectric technology can be scaled down in size without changing their thermal-to-electrical energy conversion efficiency and this is a major advantage for localized cooling of tiny electronic devices. This effect is already used for temperature control in devices such as infrared sensors and laser diodes, and has also been used to provide low-temperature refrigeration for cryogenic electronic devices like superconducting sensors.

However, the lack of [materials](#) with suitable thermoelectric efficiency for practical cooling [applications](#) at temperatures below 250 K (approximately -23°C) has driven researchers at Nagoya University to look at the effectiveness of new compounds for truly low-[temperature](#) applications.

"We studied the [thermoelectric properties](#) of whisker-like crystals composed of a compound of tantalum, silicon and tellurium," says corresponding author Yoshihiko Okamoto from Nagoya University's Department of Applied Physics. "These crystals produced very high thermoelectric powers over a wide temperature range, from the cryogenic level of 50 K (which is around -223°C) up to room temperature, but still maintained the low electrical resistivity that is needed for practical cooling applications." The samples that were grown for the experiments included pure Ta_4SiTe_4 and other crystals that were chemically doped with low levels of molybdenum and antimony.

Various material properties were measured for the samples, including thermoelectric [power](#), electrical resistivity, and thermal conductivity, to compare the effects of the two dopants on their thermoelectric characteristics. "We measured a very high thermoelectric power factor at an optimum temperature of 130 K," adds Okamoto. "However, this optimum temperature could be controlled over a very broad range by varying the chemical doping, and indicates that these crystals are suitable for practical low-temperature use."

Addition of as little as 0.1 percent molybdenum doping caused the resistivity of the telluride-type crystals to decrease dramatically at low temperatures, while they also demonstrated high thermoelectric powers that were closely related to the strongly one-dimensional electronic structures of the materials. The power factors of the crystals at room temperature greatly exceeded the corresponding values of the conventional Bi₂Te₃-based alloys that are commonly used in thermoelectric applications, and these crystals thus represent a highly promising route towards the development of high-performance thermoelectric [cooling](#) solutions at very low temperatures.

More information: Takumi Inohara et al. Large thermoelectric power factor at low temperatures in one-dimensional telluride TaSiTe, *Applied Physics Letters* (2017). [DOI: 10.1063/1.4982623](https://doi.org/10.1063/1.4982623)

Provided by Nagoya University

Citation: One-dimensional crystals for low-temperature thermoelectric cooling (2017, May 24) retrieved 19 April 2024 from <https://phys.org/news/2017-05-one-dimensional-crystals-low-temperature-thermoelectric-cooling.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.