

How good metals go bad: Discovery explains unexpected properties of exotic metallic compounds

March 15 2021



Credit: Vienna University of Technology

New measurements have solved a mystery in solid state physics: How is it that certain metals do not seem to adhere to the valid rules?

Metals are usually considered to be solid, unbreakable materials that conduct electricity and exhibit a typical metallic sheen. The behavior of classical metals, for example, their electrical conductivity, can be explained with well-known, well-tested physical theories.

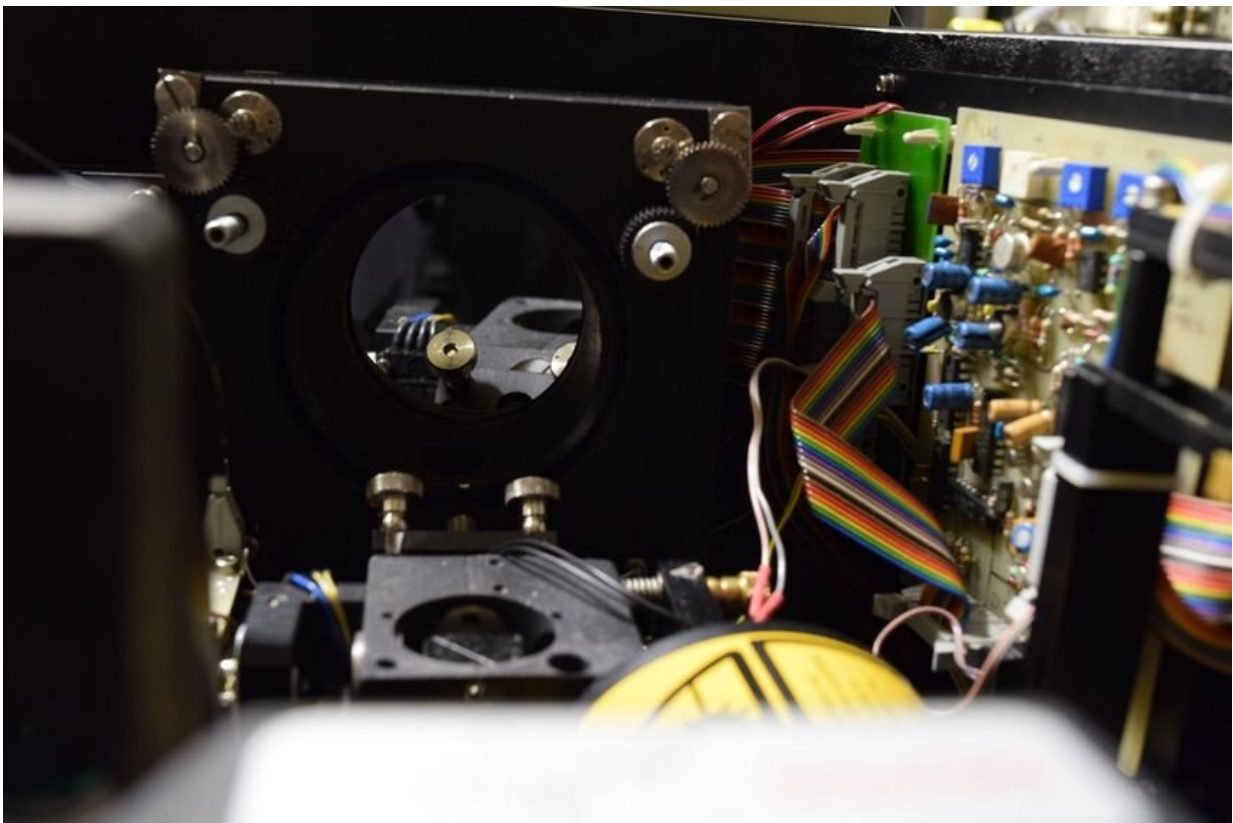
But there are also more exotic metallic compounds that pose riddles: Some alloys are hard and brittle, special metal oxides can be transparent. There are even materials right at the border between metal and insulator: tiny changes in chemical composition turn the metal into an insulator—or vice versa. In such materials, metallic states with extremely poor [electrical conductivity](#) occur; these are referred to as "bad metals." Until now, it seemed that these "bad metals" simply could not be explained with conventional theories. New measurements now show that these metals are not that "bad" after all. Upon closer inspection, their behavior fits in perfectly with what we already knew about metals.

Small change, big difference

Prof. Andrej Pustogow and his research group at the Institute for Solid State Physics at TU Wien (Vienna) are conducting research on special metallic materials—small crystals that have been specially grown in the laboratory. "These crystals can take on the properties of a metal, but if you vary the composition just a little bit, we are suddenly dealing with an insulator that no longer conducts electricity and is transparent like glass at certain frequencies," says Pustogow.

Right at this transition, one encounters an unusual phenomenon: the [electrical resistance](#) of the metal becomes extremely large—larger, in fact, than should be possible at all according to conventional theories. "Electrical resistance has to do with the electrons being scattered at each

other or at the atoms of the material," explains Andrej Pustogow. According to this view, the greatest possible electrical resistance should occur if the electron is scattered at every [single atom](#) on its way through the material—after all, there is nothing between an atom and its neighbor that could throw the electron off its path. But this rule does not seem to apply to so-called "bad metals": They show a much higher resistance than this model would allow.



Inside the optical spectrometer. Credit: Vienna University of Technology

It all depends on the frequency

The key to solving this puzzle is that the material properties are frequency-dependent. "If you just measure the electrical resistance by applying a DC voltage, you only get a single number—the resistance at zero frequency," says Andrej Pustogow. "We, on the other hand, made optical measurements using light waves with different frequencies."

This showed that the "bad metals" are not so "bad" after all: At low frequencies they hardly conduct any current, but at higher frequencies they behave as one would expect from metals. The research team considers tiny amounts of impurities or defects in the material, that can no longer be adequately shielded by a metal at the boundary to an insulator, as a possible cause. These defects can cause some areas of the crystal to no longer [conduct electricity](#) because there the electrons remain localized in a certain place instead of moving through the material. If a DC voltage is applied to the material so that the electrons can move from one side of the crystal to the other, then virtually every electron will eventually hit such an insulating region and current can hardly flow.

At high AC frequency, on the other hand, every electron moves back and forth continuously—it does not cover a long distance in the crystal because it keeps changing direction. This means that in this case many electrons do not even come into contact with one of the insulating regions in the crystal.

Hope for important further steps

"Our results show that optical spectroscopy is a very important tool for answering fundamental questions in [solid-state physics](#)," says Andrej Pustogow. "Many observations for which it was previously believed that exotic, novel models had to be developed could very well be explained by existing theories if they were adequately extended. Our measurement method shows where the additions are necessary." Already in earlier

studies, Prof. Pustogow and his international colleagues gained important insight into the boundary region between [metal](#) and insulator, using spectroscopic methods, thus establishing a fundament for theory, .

The metallic behavior of materials subject to strong correlations between the electrons is also particularly relevant for so-called "unconventional superconductivity"—a phenomenon that was discovered half a century ago but is still not fully understood.

More information: Andrej Pustogow et al. Rise and fall of Landau's quasiparticles while approaching the Mott transition, *Nature Communications* (2021). [DOI: 10.1038/s41467-021-21741-z](https://doi.org/10.1038/s41467-021-21741-z)

Provided by Vienna University of Technology

Citation: How good metals go bad: Discovery explains unexpected properties of exotic metallic compounds (2021, March 15) retrieved 18 April 2024 from <https://phys.org/news/2021-03-good-metals-bad-discovery-unexpected.html>

<p>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.</p>
--