

# Giant increase in conductivity measured when a semiconductor is submitted to high pressure

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ICN2 Oxide Nanoelectronics Group has obtained conductivity values for strontium iridate 250 times higher than in normal conditions by pressing it with nanometric needles. The results, published in *Nanoscale*, were obtained via an atomic force microscope (AFM) showing that the material could become a good candidate for future applications in sensors and electronics.

Researchers from the Catalan Institute of Nanoscience and Nanotechnology (ICN2) have measured, at room temperature, the highest values of piezoresistivity ever detected in an electroceramic material, overcoming the registers for materials such as silicon nanowires or graphene. Moreover, it was measured with a simple technique that avoids the use of complex equipment to control pressure. The research has been conducted by Oxide Nanoelectronics Group, led by Prof ICREA Gustau Catalan. Dr Neus Domingo is the first signer of the article published in *Nanoscale* and her contribution has been essential for the development of the research.

Piezoresistivity happens when certain materials change their [electric conductivity](#) when a deforming pressure is applied. This is due to the fact that isolator and semiconductor materials have very special electrical characteristics which result in bands with different proprieties: the [valence band](#), where electrons are 'parked', and the [conduction band](#), where the electric current flows. These bands are separated by an energy

gap; when the gap is thin, the number of electrons in the conduction band is higher and, consequently, the electric conductivity is higher too.

When pressure is applied on certain semiconductor materials, the band gap which separates the conduction band and the valence band is modified. This allows electrons to jump to the conduction band, consequently decreasing the electric resistance of the material. In other words, when the material is pressed, there is better electricity conduction. This fact leads to a wide range of possible applications, from [pressure sensors](#) to microelectronic transistors where the current is controlled by pressure instead of voltage.

## A nanoscopic needle to study high pressures

At the ICN2 laboratories, Prof. Catalan's Group measured a giant piezoresistivity in a ceramic material, strontium iridate ( $\text{Sr}_2\text{IrO}_4$ ). The measures were made with an [atomic force microscope](#) (AFM), a device that uses nanoscopically sharpened needles that press the material and quantify its conductivity at the same time. This is a new and imaginative way to use this equipment, because it is the first time that the AFM needle is used to measure a material's piezoresistivity.

The AFM needle is so small that a minuscule force translates to a high pressure value. Less than 1mg of force (approximately an ant's weight) applied over a nanoscopic needle is converted to a pressure value of over 100 tons (the weight of 20 elephants) per square centimeter. In fact, the pressure is so high (to 10GPa) that diamond tips had to be used to prevent the needle from crushing.

With this [pressure](#) level, researchers have obtained conductivity values for  $\text{Sr}_2\text{IrO}_4$  250 times higher than in normal conditions. Remarkably, despite applying deformations over 500 times, the sample did not suffer any damage. Moreover, the piezoresistivity has been measured at [room](#)

[temperature](#). In conclusion, this semiconductor could be a good candidate for future applications in sensors, new kinds of transistors and other specialized electronic devices. However, iridium is a scarce element on our planet, so scientists are looking for alternative materials.

**More information:** Domingo, N., López-Mir, L., Paradinas, M., Holy, V., Železný, J., Yi, D., Suresha, S.J., Liu, J., Rayan Serrao, C., Ramesh, R., Ocal, C., Martí, X., and Catalan, G. (2015). "Giant reversible nanoscale piezoresistance at room temperature in Sr<sub>2</sub>IrO<sub>4</sub> thin films." *Nanoscale*, 2015; 7: 3453-3459. DOI: [10.1039/C4NR06954D](https://doi.org/10.1039/C4NR06954D)  
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