Newly discovered properties of ferroelectric crystal shed light on branch of materials

July 10 2018

In ferroelectric materials the crystal structure distorts, giving rise to a spontaneously formed polarization and electric field. Because of this unique property, ferroelectrics can be found in anything from ultrasound machines and diesel fuel injectors to computer memory. Ferroelectric materials are behind some of the most advanced technology available today. Findings that ferroelectricity can be observed in materials that exhibit other spontaneous transitions, like ferromagnetism, have given rise to a new class of these materials, known as hybrid improper ferroelectrics. The properties of this type of material, however, are still far from being fully understood. New findings published in *Applied Physics Letters*, help to shine light on these materials and indicate potential for new optoelectronic and storage applications.

A team of researchers from China has characterized one type of hybrid improper ferroelectric, Ca3Mn2O7. The group investigated the material's ferroelectric, magnetoelectric and optical properties. They were able to demonstrate ferroelectricity in Ca3Mn2O7 as well as coupling between its magnetism and ferroelectricity, a key property that has potential to allow for faster and more efficient bit operations in computers.

"Our work solves a long-term puzzle in this field, which could push forward the frontiers and enhance the confidence to continue the research in this field," said Shuai Dong, an author on the paper.

Like batteries, for instance, ferroelectrics have positively and negatively

charged poles. A major distinguishing feature of these materials, however, is that this polarization can be reversed by using an external electric field.

"This can be useful because it can be used in devices to store information as ones and zeros," Dong said. "Also, the switching of polarization can generate current, which can be used in sensors."

Unlike traditional ferroelectrics, which directly derive their properties from polar distortions in the lattice of the material's crystal, hybrid improper ferroelectrics generate polarization from a combination of nonpolar distortions.

When hybrid improper ferroelectrics were first theorized in 2011, two materials were proposed. In the years since, nonmagnetic Ca3Ti2O7¬ crystals were demonstrated experimentally, but a full characterization of its magnetic counterpart, Ca3Mn2O7, remained elusive.

"Multiple transitions as well as phase separations were evidenced in Ca3Mn2O7, making it more complex than the early theoretical expectations," Dong said. "This material is complex, and the leakage is serious, which prevents the direct measurement of its ferroelectricity in high temperature."

To further understand Ca3Mn2O7, Dong and his collaborators confirmed the material's ferroelectricity using pyroelectric measurements that examine its electric properties across a range of temperatures as well as measured Ca3Mn2O7's ferroelectric hysteresis loops, a method that mitigates some extrinsic leakage. Further investigation showed that Ca3Mn2O7 exhibits a weak ferromagnetism that can be modulated by an electric field.

It was found that Ca3Mn2O7, a material long-rumored to have

ferroelectric and magnetoelectric properties, also exhibited strong visible light absorption in a band gap well suited for photoelectric devices. This feature of Ca3Mn2O7 might pave the way for the material to be used in anything from photovoltaic cells to light sensors with the built-in electric field leading to larger photogenerated voltage than today's devices.

"The most surprising thing for us was that no one noticed its prominent light absorption before," Dong said.

In the future, Dong said he hopes to explore Ca3Mn2O7's photoelectric properties as well as investigate whether introducing iron to the crystal would enhance its magnetism.

More information: "Direct observation of ferroelectricity in Ca3Mn2O7 and its prominent light absorption," *Applied Physics Letters* (2018). DOI: 10.1063/1.5037525

Provided by American Institute of Physics