Photodielectric discovery brings new optical control to electronics

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Characters in some of the more futuristic science fiction films, like "Minority Report" and "Iron Man," control computer displays with slick and deliberate hand motions. In "Minority Report," the protagonist, played by Tom Cruise, uses gloves that glow at the fingertips and give him the power of virtual manipulation. The light seems to allow him to control the screen as if it were a touchscreen, but he's touching nothing but air.

That technology is still science fiction, but a new study may bring it closer to reality. A team of researchers from Japan reports this week in *Applied Physics Letters*, that they have discovered a phenomenon called the photodielectric effect, which could lead to laser-controlled touch displays.

A number of basic circuit components have been developed beyond their traditional electricity-based designs to instead be controlled with light, such as photo-resistors, photodiodes, and phototransistors. However, there isn't yet a photo-capacitor.

"A photo-capacitor provides a novel way for operating electronic devices with light," said Hiroki Taniguchi of the University of Nagoya in Japan. "It will push the evolution of electronics to next-generation photo-electronics."

Capacitors are basic components for all kinds of electronics, acting somewhat like buckets for electrons that can, for example, store energy or filter unwanted frequencies. Most simply, a capacitor consists of two parallel conducting plates separated by an electrically insulating material, called a dielectric, such as air or glass. Applying a voltage across the plates causes opposing (and equal) charges to build up on both plates.

The dielectric's properties play a determinate role in the electric field profile between the plates and, in turn, how much energy the capacitor can store. By using light to increase a property of the dielectric called permittivity, Taniguchi and his colleagues hope to create light-controlled capacitors.

Previous researchers have achieved a type of photo-dielectric effect using a variety of materials, but relied on photo-conductance, where light increased the materials electrical conductivity. The rise in conductance, it turns out, leads to greater dielectric permittivity.

But this type of extrinsic photodielectric effect isn't suitable for practical applications, Taniguchi said. A capacitor must be a good insulator, preventing electrical current from flowing. But under the extrinsic photodielectric effect, a capacitor's insulating properties deteriorate. In addition, such a capacitor would only work with low-frequency alternating current.

Now Taniguchi and his colleagues have found an intrinsic photodielectric effect in a ceramic with the composition LaAl9.9Zn0.01O3-δ. "We have demonstrated the existence of the photodielectric effect experimentally," he said.

In their experiments, they shined a light-emitting diode (LED) onto the ceramic and measured its dielectric permittivity, which increased even at high frequencies. But unlike prior experiments that used the extrinsic photodielectric effect, the material remained a good insulator.

The lack of a significant loss means the LED is directly altering the dielectric permittivity of the material, and, in particular, is not increasing conductance, as is the case with the extrinsic effect. It's still unclear how the intrinsic photodielectric effect works, Taniguchi said, but it may have to do with defects in the material.

Light excites electrons into higher (quantized) energy states, but the quantum states of defects are confined to smaller regions, which may be preventing these photo-excited electrons from traveling far enough to generate an electric current. The hypothesis being that the electrons remain trapped which leads to more electrical insulation of the dielectric material.

More research is needed before we'll see light-controlled screens, but the work is a significant step for the field. Further research will look to enhance the effect even more, minimize any energy dissipation due to a drop of dielectric properties, and optimize the material fabrication process, Taniguchi said. Further studies may also reveal new materials better suited for other electronics applications.

More information: Takayuki Nagai et al, Optical control of dielectric permittivity in LaAlZnO, *Applied Physics Letters* (2017). DOI: 10.1063/1.4979644

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