# The piezoelectric effect in liquids

Why does Quartz exhibit the piezoelectric effect? Why has the effect not been observed in liquids till now? In what type of liquid has it now been discovered? What are the applications of this new discovery? Will it have any environmental benefits?

**EXPLAINER**

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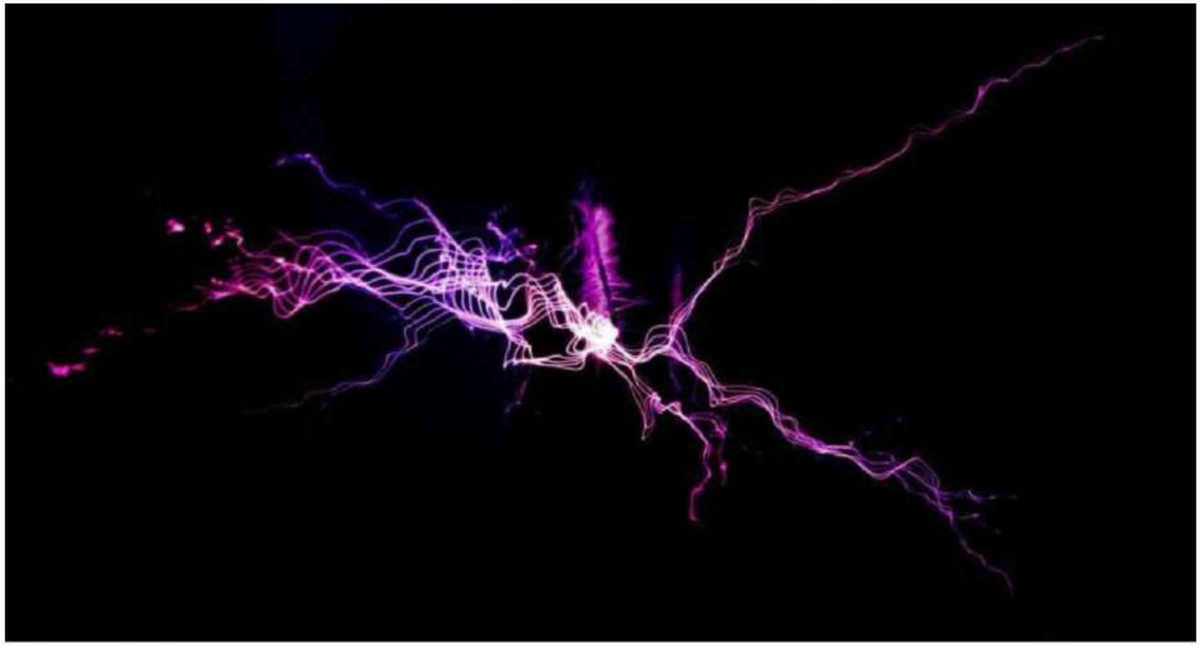
**The story so far:**

For the first time, scientists have reported evidence of the piezoelectric effect in liquids. The effect has been known for 143 years and in this time has been observed only in solids. The new finding challenges the theory that describes this effect as well as opens the door to previously unanticipated applications in electronic and mechanical systems. The effect was found in pure 1-butyl-3-methyl imidazolium bis(trifluoromethyl-sulfonyl)imide and 1-hexyl-3-methyl imidazolium bis(trifluoromethylsulfonyl)imide – both ionic liquids (liquids which are made of ions instead of molecules) at room temperature. The study paper was published in the *Journal of Physical Chemistry Letters*.



An illustration of an electric current. NIKHITA SINGHAL/UNSPLASH

### What is the piezoelectric effect?

In the piezoelectric effect, a body develops an electric current when it is squeezed. Quartz is the most famous piezoelectric crystal; it is used in analog wristwatches and clocks. Such crystals are also used in other instruments where converting mechanical stress to a current is useful.

Quartz is silicon dioxide ($SiO_2$). The quartz crystal consists of silicon and oxygen atoms at the four vertices of a three-sided pyramid; each oxygen atom is shared by two pyramids. These pyramids repeat themselves to form the crystal. The effective charge of each pyramid is located slightly away from the centre. When a mechanical stress is applied, that is when the crystal is squeezed, the position of the charge is pushed further from the centre, giving rise to a small voltage. This is the source of the effect.

### Why is the effect in liquids surprising?

The reason the piezoelectric effect has only been expected in solids thus far is that the body being squeezed needs to have an organised structure, like the pyramids of quartz. Liquids don't have such structure as they take the shape of the container.

Physicists explain the effect using a combination of Hooke's law – that the force required to squeeze an object is linearly (i.e. non-exponentially) proportional to the amount of squeezing – and the properties of dielectric materials. These are materials that don't conduct electricity but whose electrons are still mildly affected by an electric field. Hooke's law is not clear when the body isn't very compressible.

"While I am unwilling to claim this requires a complete rethink of the physics of piezoelectrics, the observation of the effect in ionic liquids appears on its face to be inconsistent with the current model," Gary Blanchard, a professor at the Department of Chemistry, Michigan State University, and a coauthor of the paper, told *The Hindu*. "An implication of our findings is the existence of some manner of organisation in ionic liquids that is not seen in 'normal' liquids." Indeed, their discovery will have to be modelled in ionic liquids specifically. This is because, according to the paper, 'normal' and ionic liquids of the kind tested in the study respond very differently, at the molecular level, when an electric charge is "imposed" on them.

"Within the framework of the current understanding, the piezoelectric effect requires 'persistent' order within the material," Dr. Blanchard explained. "Normal liquids and gases have not been shown to exhibit order that persists long enough to be observed and characterised."

### What new applications are possible?

According to the paper, "The discovery ... opens the door to applications that have previously not been accessible with solid-state materials, and [room-temperature ionic liquids] are more readily recyclable and in many instances pose fewer environmental issues than many currently used piezoelectric materials."

The liquids also displayed the inverse piezoelectric effect: they became distorted when an electric charge was applied. Dr. Blanchard told the magazine IEEE *Spectrum* that this fact could be used to control how the liquids bent light passing through them by passing different currents through them. That is, using this simple control mechanism, vials of these liquids could be lenses with dynamic focusing abilities.

"I believe the most pressing matter is to develop a theoretical framework with predictive power to understand these experimental observations," Dr. Blanchard stated.

Having a theory to explain the liquids' behaviour could reveal why these liquids behave the way they do, which in turn could reveal better ways to develop newer applications.

## THE GIST

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