Manipulating heat flows with an electric field

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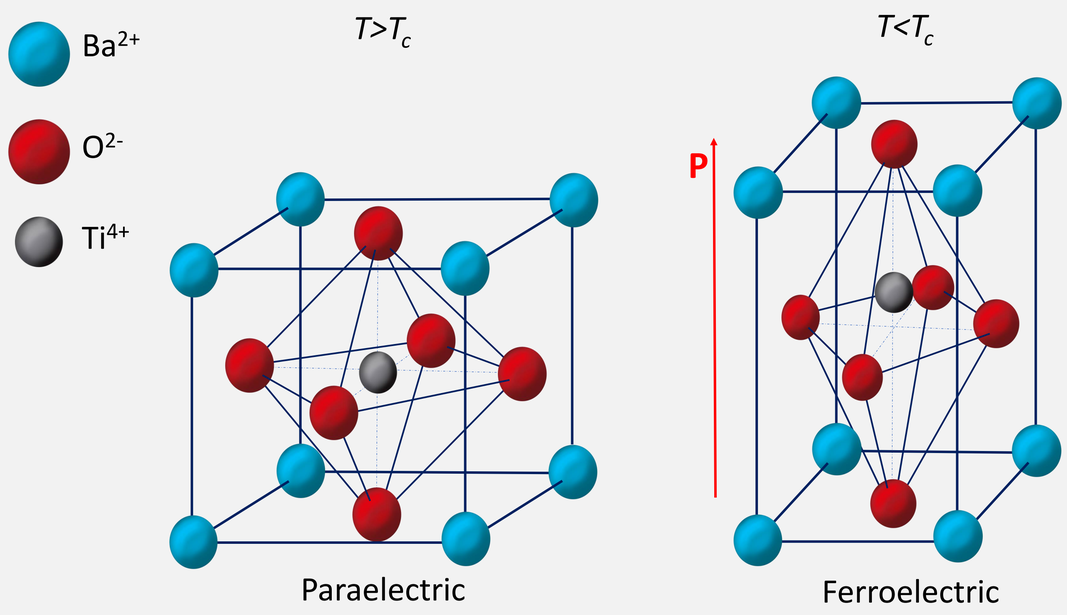
Control of charge flows led to the invention of the transistor and all related electronic devices of our daily life. In contrast, manipulating heat flows is still a challenge. Yet, heat management is essential in electronic circuits and may lead to the development of a new paradigm of logic (phononics)[1].

A new paradigm of logic

Just as electronics uses electrons in electricity, phononics can use phonons in heat flows in order to make thermal devices. In such circuits, heat flows must be controled dynamically.

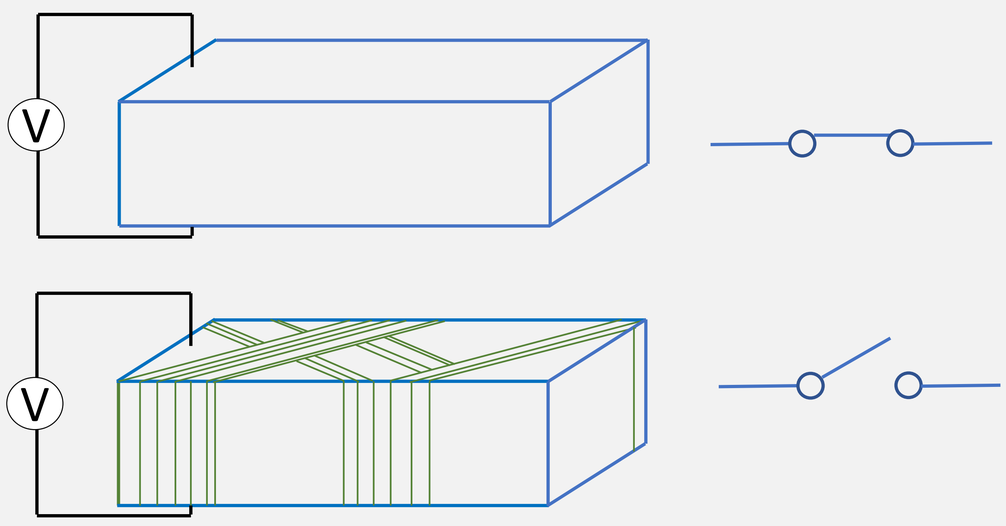
Fig. 1: $BaTiO_3$ polarization with electric field



In order to control phonon flux, this research focuses on a way to control efficiently the thermal conductivity of a device. Ferroelectric oxides such as $BaTiO_3$ possess an electric polarization that can be controled by an external electric field[4].

Example of phononic device

Fig. 2: Theoritical thermal switch with $BaTiO_3$



As demonstrated on this schematics, $BaTiO_3$ might be an efficient compound to develop a thermal switch by blocking the heat flow with a high domain wall density (aka low thermal conductivity).

Thermal conductivity in $BaTiO_3$

Domain walls impact the propagation of phonons conducting heat[2,3]. An increase in density of domain walls leads to an increase of collisions between phonons and domain walls and thus reduces the thermal conductivity.

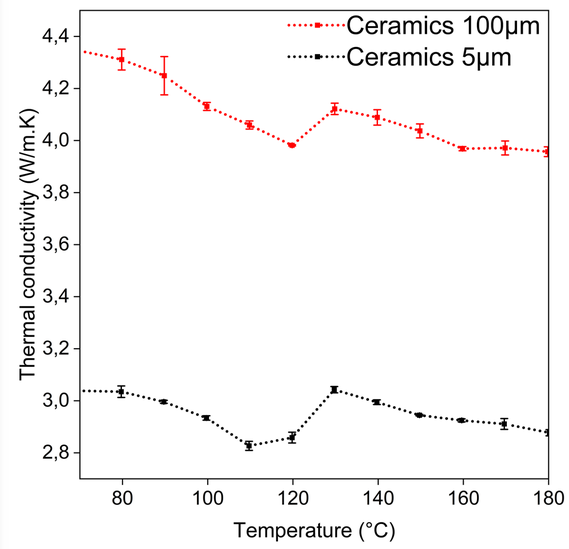


Fig. 3: Thermal conductivity by laser-flash method for different grain sizes

$BaTiO_3$ domain walls under electric field

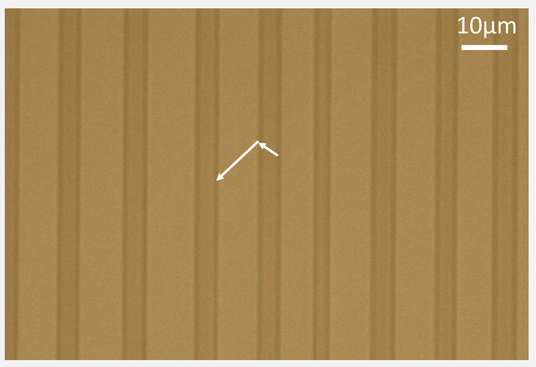


Fig. 4: Domains with domain walls (darker) and their polarization.

Temperature is not the only way to control the density of domain walls, the application of an electric field can also have an effect on it.

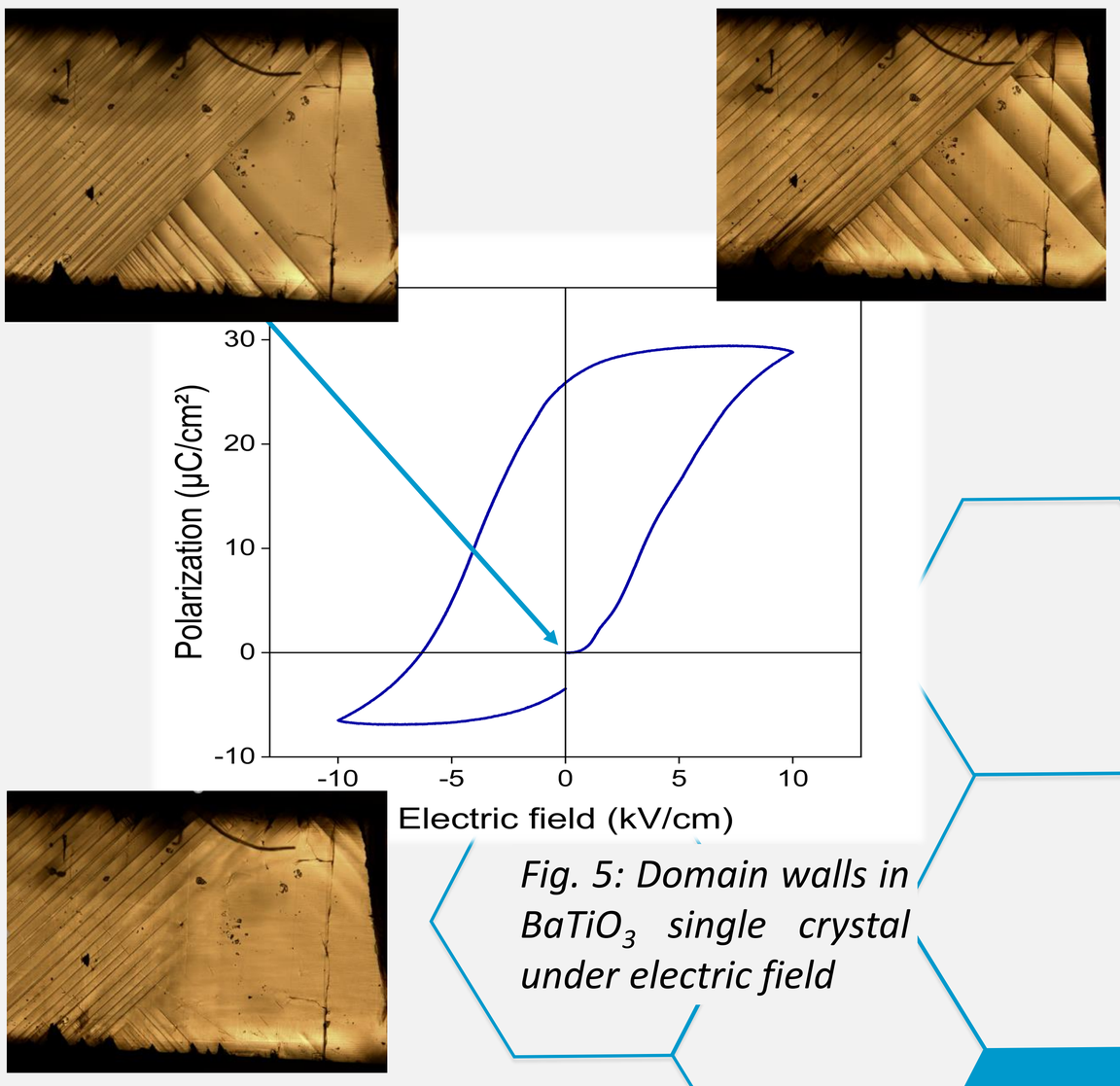


Fig. 5: Domain walls in $BaTiO_3$ single crystal under electric field

$BaTiO_3$ is a good compound to study in order to develop devices for a new paradigm of logic; the phononics. Domain walls decrease the thermal conductivity, moreover they can be controlled either by temperature or an electric field. This property makes it a tunable thermal device perfect for phononic applications.

References
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[2] E. Langenberg et al., Nano Lett. 19, 007901 (2019)
[3] J.A. Seijas-Bellido et al., Phys. Rev. B. 96, 140101 (2017)
[4] B. Casals, G.F. Nataf, E.K.H. Salje, Nat. Commun. 12, 345 (2021)

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