Novel Effects Induced by Inversion Symmetry Breaking

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Abstract

Being a core role in modern physics, symmetry determines material properties and device performance at the fundamental level. As pinpointed by Pierre Curie in 1894, it is symmetry breaking that creates physical properties. Manipulating material symmetry, especially that breaks centrosymmetry, has been a versatile approach to develop new physical properties and novel functionalities, which are otherwise forbidden in their pristine structure. Here, I will introduce three emerging effects developed in my research by engineering material symmetry, i.e., the interface piezoelectric effect, interface pyroelectric effect, and the bulk photovoltaic effect.

Interface asymmetry in heterostructures has given rise to many interesting phenomena in condensed matters. we demonstrated that a built-in electric field in the heterostructure that originates from band bending at the interface induces polar symmetry therein and enables the piezoelectric and pyroelectric effects.[1] These interface effects not only extend their application scope but also brings additional degrees of freedom to optimize their performance. In comparison to the conventional bulk piezo-/pyroelectric effects, these interface effects apply to materials of any symmetry and exhibit extraordinary performance. Furthermore, deliberate control of interface asymmetry allows the unprecedented manifestation of the negative Poisson's ratio in the piezoelectric effect.

In addition, the bulk noncentrosymmetry in semiconductors enables the conversion of solar energy to electricity in a junction-free geometry. This intriguing effect, termed the bulk photovoltaic effect, originates from the asymmetric distribution of photo-excited carriers in momentum/real space and only functions in non-centrosymmetric materials. By virtue of its distinctive mechanism, it can potentially boost the efficiency of solar cells. We will show that mechanical modulation of the semiconductor symmetry not only induces a colossal enhancement of the bulk photocurrent but also allows it to manifest in materials regardless of their pristine symmetry.[2][3] This enables to optimize its performance from a wide pool of established semiconductive materials.

References:

[1] M.-M. Yang *et al.* Nature **584**, 377 (2020).

[2] M.-M. Yang *et al.* Nature Communications **10**, 2791 (2019).

[3] M.-M. Yang *et al.* Science **360**, 904 (2018).