

Microscopic formulation of magneto-piezoelectric effect in a quarter-metal state

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In recent years, rhombohedrally stacked multilayer graphene has attracted much attention as fertile ground for exploring correlated quantum phenomena. Its electrically tunable flat bands host a rich variety of ground states with flavor symmetry breaking. In particular, at low electron densities, the emergence of a quarter-metal state—in which both spin and valley degrees of freedom are polarized—is suggested [1,2]. Furthermore, signatures of chiral superconductivity with spontaneously broken time-reversal symmetry have been reported in rhombohedral tetralayer and pentalayer graphene [2]. Although many theoretical studies on this exotic state have been reported, experimental methods to identify the spin-valley polarization remain limited.

We investigate the magneto-piezoelectric effect (MPE), a cross-correlated response between electric current and strain [3], in the quarter-metal state. This effect is allowed in systems lacking both time-reversal and inversion symmetries and may therefore provide a good probe of the symmetry breaking associated with the quarter-metal state. Furthermore, since the contribution of strain in honeycomb lattice systems is represented in the form of pseudo gauge field [4], the input current-induced strain can generate a pseudo magnetic field which works in the opposite direction for the each valley. By explicitly incorporating microscopic electron-phonon interactions, we formulate the MPE by using Green's function method in order to discuss spatially nonuniform responses beyond the uniform limit.

[1] H. Zhou et al., *Nature* **598**, 429 (2021).

[2] T. Han et al., *Nature* **643**, 654 (2025).

[3] H. Watanabe et al., *Phys. Rev. B* **96**, 064432 (2017).

[4] H. Tanaka et al., *Phys. Rev. B* **113**, L201114 (2026).