Elliptical Planar Hall Effect Sensors via Non-Collinear Anisotropy Engineering

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Magnetic field sensing is a key enabling technology in automotive, biomedical, and industrial applications. Among magnetoresistive devices, planar Hall effect (PHE) sensors provide high sensitivity, low detection limits, and good thermal stability. Elliptical PHE (EPHE) sensors are especially attractive because elongated ferromagnetic ellipses induce a well-defined in-plane uniaxial shape anisotropy that stabilizes coherent single-domain rotation.

Conventional EPHE sensors are fabricated in a collinear scheme where a growth-induced anisotropy H_g (imprinted during deposition) and the shape-induced anisotropy H_s are aligned along the same in-plane easy axis. The two contributions therefore add,

$$H_{\text{eff}} = H_s + H_g,$$

which imposes a floor $H_{\text{eff}} \geq H_g$ and limits access to the ultra-low-anisotropy regime. Here we introduce anisotropy-orientation engineering as a fabrication-compatible route to overcome this constraint. During deposition we imprint a growth-defined easy axis, and the ellipses are subsequently patterned at a controlled in-plane angle relative to it. Mixing two uniaxial anisotropies at an arbitrary angle reduces exactly to a single effective anisotropy $(H_{\text{eff}}, \phi_{\text{eff}})$. In the orthogonal configuration the contributions partially compensate,

$$H_{\text{eff}} = |H_s - H_g|,$$

enabling $H_{\text{eff}} < H_g$ through balancing rather than scaling.

We demonstrate this principle in two systematic device series: thickness-tuned and size-tuned EPHE sensors. The effective anisotropy parameters are extracted from angular PHE measurements using coherent-rotation Stoner–Wohlfarth fits. Reducing H_{eff} directly improves sensitivity and magnetic resolution. For example, decreasing H_{eff} from 5.4 Oe to 3.8 Oe lowers the equivalent magnetic noise at 1 Hz from 50.3 to 38.3 $\text{pT}/\sqrt{\text{Hz}}/\text{A}$.

These results establish anisotropy orientation as a footprint-preserving design degree of freedom for realizing ultra-low effective anisotropy fields and optimizing magnetic resolution in rotation-based PHE sensors.