MINIATURIZED DELTA-E EFFECT MAGNETIC FIELD SENSORS

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Delta-E effect magnetic field sensors exploit the change in the mechanical stiffness tensor of a magnetostrictive material when a magnetic field is applied, resulting in a shift in the resonance frequency. These sensors have demonstrated the capability to detect small amplitude and low-frequency magnetic fields. However, achieving high spatial resolutions and fabricating compact arrays with millimeter-sized sensors remains challenging. Moreover, the resonator fabrication process introduces anisotropic stress into the magnetic layer, resulting in poor reproducibility [1]. Additionally, the performance of cantilever-type sensors is affected by inhomogeneous magnetic properties at their clamping region [2]. Here, we present a shadow mask deposition technique and a free-free microresonator design for sub-millimeter-sized delta-E effect magnetic field sensors to minimize residual stress, ensure homogeneous magnetic properties, and enhance reproducibility. By employing displacement measurements and a magneto-mechanical model, the residual stress induced by the deposition of the FeCoSiB magnetic layer and its impact on the effective magnetic anisotropy are determined, achieving a homogeneous magnetoelastic anisotropy below 500 J/m^3. Magneto-optical measurements are used to analyze local magnetic behaviors. We identify different resonance modes and explore the correlation between sensitivities and spatial magnetic and mechanical properties. The signal and noise performance of various sensor geometries are investigated. High device-to-device reproducibility with a resonance frequency deviation of $\leq$0.2% is achieved. Overall, we demonstrate highly reproducible miniaturized delta-E effect sensors using the proposed deposition technique and sensor design. These results represent a significant step towards fully integrated sensor arrays, offering the potential for higher spatial resolution and improved detection limits through compact arrays.

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References

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