

Emergent magneto-inductance effect in Au/NiFe thin films on flexible substrates at room temperature

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Emergent inductance, a quantum phenomenon in spintronics arising from the interaction between spin dynamics and charge transport in magnetic materials, has garnered significant attention due to its unique properties. The concept is developed and practically achieved based on theoretical studies on Berry phase dynamics and emergent electromagnetic fields induced by current driven motion of non-collinear spin structures [1–4]. Unlike classical inductance, the magnitude depends inversely on the cross-sectional area of devices, which inspires the advancements in the inductor miniaturization and flexible magnetic sensors for spintronic applications [2–6]. In this study, we present an emergent magneto-inductance (EML) effect in Au/NiFe thin films on flexible ultra-smooth Polyimide (us-PI) substrates (XENOMAX®; TOYOBO Co., Ltd.), demonstrating a large inductance variation under a small magnetic field.

Au and Ni₈₁Fe₁₉ (permalloy, Py) thin films were sequentially deposited onto us-PI substrates using thermal evaporation under a base pressure below 2×10^{-5} Pa. During deposition, a magnetic field of 360 Oe was applied along the transverse direction (y-axis, as illustrated in Fig. 1) to induce magnetic anisotropy in Py layer. The EML effect was investigated across various frequencies through AC 2-probe measurement, using an LCR meter with an external magnetic field of up to ± 250 Oe.

The EML result presented in Fig. 2 reveals a clear inductance variation in the Au/Py/us-PI under the magnetic fields below 10 Oe at room temperature. The magnitude of EML variation, ΔL , in Au/Py/us-PI reaches 809 nH when the thickness of Au/Py is 48 nm and the film width is 1.5 mm. As shown in Fig. 3, the ΔL exhibits a clear increase with decreasing the film width, which is consistent with our previous study [5,6]. The EML effect is attributed to the spin motive force which results from the transient domain-wall motion driven by an AC current under a stepwise external magnetic field. Our study may offer the potential for the research of unconventional inductors and the integration of planar inductors into micro-devices in spin electronics.

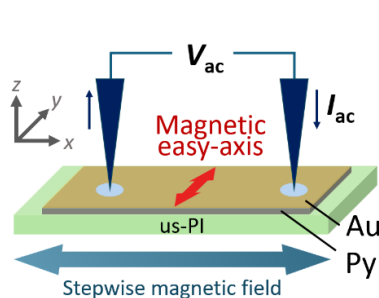


Fig. 1 Schematic illustration of the EML measurement.

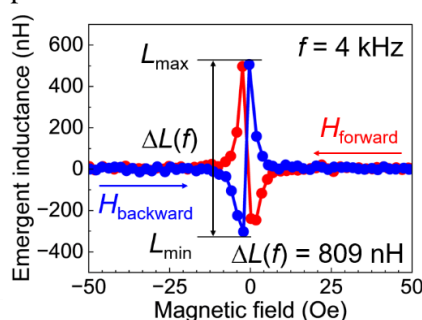


Fig. 2 EML curves of Au/Py/us-PI at 4 kHz.

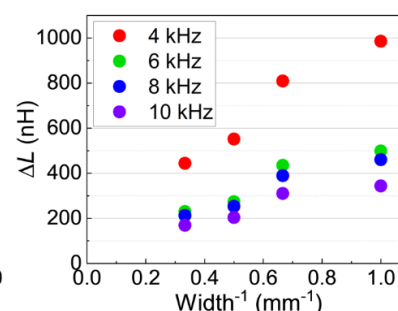


Fig. 3 Film width dependence of EML in Au/Py/us-PI.

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