Challenges in MTJ Sensor Performance and MFC-Based Solutions

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Magnetic tunnel junction (MTJ) sensors are limited in further detectivity improvement due to 1/f noise, while micro-electromechanical systems (MEMS) integrated with magnetic flux concentrators (MFCs) offer an effective solution for suppressing 1/f noise and modulating low-frequency magnetic fields. A key challenge in fabricating miniaturized, low-noise MEMS magnetoresistive sensors lies in the preparation of high-performance MFCs. To address this for MEMS-MTJ hybrid magnetic sensors, this study adopted a novel Ta/$Ni_{77}Fe_{14}Cu_5Mo_4$ laminated structure, which reduced the coercivity of the magnetic film by dozens of times; optimized sputtering power further achieved a relative permeability of 3246. Simulation results indicated that the MTJ-MEMS hybrid sensor employing this magnetic film reached a modulation efficiency of 65.4%, maintaining competitiveness among comparable devices. A sensor prototype with 400-nm-thick MFCs was successfully fabricated via process optimization, enhancing MTJ sensitivity by 2.2 times. Notably, the high-frequency noise power spectral density of the MTJ was reduced by a factor of 686 compared to its low-frequency noise. These findings position MTJ sensors as highly competitive candidates for ultra-weak magnetic field detection applications.