Integration of Magnetic Thin Films into On-chip Inductor: NiFe vs CoZrTaB

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Motivation
- On-chip inductors are a critical element in power circuit for PwrSoC/SiP.
- Need high inductance density -> Reduces chip area -> Reduces cost.
- High quality factor -> Reduces loss -> Reduces power supply.
- On-chip inductors with magnetic materials
  - High permeability, high resistivity, high FMR for GHz applications.
  - CMOS compatibility: low process temperature, stable properties.

Device Fabrication
- Spiral (W: 88 µm, L:160 µm) and stripline (W: 9 µm, L: 450 µm)
  inductors were fabricated on quartz substrates.
- Electron Beam Lithography (EBL) used for pattern definition.
- Magnetic films and 2 µm thick copper wires deposited by magnetron sputtering.
- Low-k polyimide for insulator.

Material Characterizations
- DC magnetron sputter deposition: 80%Ni-20%Fe and Co-4%Zr-4%Ta-8%B (at.%).
- Co-Zr-Ta-B shows superior magnetic properties.
  - Low coercivity < 0.1 Oe
  - High DC permeability ~10^7 and high resistivity ~ 115 µΩ·cm
  - High FMR frequency measured by PIMM ~1.6GHz

Inductance Enhancement Of On-chip Inductors With Ni-Fe
- Spiral inductors with patterned NiFe rings at 100 m scale achieving enhancements of 6X in inductance and 3X in Quality factor at frequencies as high as 200 MHz. An inductance density around 770 nH/mm² is achieved, which is higher than other reported values of Ni-Fe based inductors.

Measurement results
- With Co-Zr-Ta-B film, a maximum 3.5X inductance increase and a 3.9X increase in the Q-factor at 1 GHz were achieved, and by using laminations, up to a 9.1X inductance increase with good frequency response up to 2 GHz can be achieved.

Optical images of the fabricated rectangular and square inductors (a) without NiFe (bare), (b) with NiFe thin film enclosed, (c) with patterned NiFe rings.

Measured and simulated curves of inductance and quality factor vs. frequency for 4-turn spiral inductors with Ni-Fe. Devices with film A (=170), B (=300) and C (=500) were investigated. L increase up to 6X is measured from device C at 200 MHz.


The measurement of layer thickness dependence of permeability. Inset shows schematic of laminated NiFe film.

Measurement result showing relative gain in L and Q at low and high frequencies.