Abstract:
On-chip RF inductors play an important role in RF integrated circuits, such as filters, amplifiers, mixers, matching networks, and oscillators. Incorporating ferromagnetic materials into the inductor structure is known to improve both the effective inductance and the quality factor (Q). However various loss mechanisms limit the high-frequency applications for such inductors, such as eddy currents and ferromagnetic resonance (FMR). Permalloy is chosen due to its high permeability, high saturation magnetization, moderate resistivity and process compatibility. Appropriate patterns are carefully designed for the permalloy thin films to reduce both losses. The resistive loss of the sputtered aluminum metal lines is identified as the main loss mechanism and hence reducing this resistive loss with alternative metal layer technology can readily enhance the Q factor.

Summary:
A CMOS compatible process has been developed. A 2 µm oxide layer is deposited on a standard (100) oriented silicon substrate by PECVD, followed by a sputtered-on and wet-etched 1 µm aluminum layer as the patterned ground plane. After the second 4 µm PECVD oxide layer, another 1 µm aluminum is sputtered on and patterned as the inductor underpass layer as the patterned. Immediately on top of the third 1.2 mm PECVD oxide layer, the patterned Ta/permalloy/Ta thin films are formed through a lift-off process. The thicknesses of Ta and permalloy are 20 nm and 200 nm respectively. The thin Ta film serves as the adhesion layer and the immigration barrier at the interface of permalloy and oxide. A final 1.3 µm PECVD oxide layer is deposited on in order to prevent the patterned permalloy thin films from shorting the top signal lines. A CMP step is performed to achieve a planar surface. When the ground plane contacts and via contacts are opened by etching the oxide, the last 1 µm Al top metal is again sputtered on and patterned as the inductor spirals.

The fabricated devices are measured using an Agilent E8361A network analyzer. For all permalloy patterns with 150 µm bar length and 2 µm bar spacing, over 35% of effective inductance enhancement is achieved, in comparison with the air-core control structure. The enhancement increases with the increase of the permalloy bar width. For patterns with 10 µm spacing, only 10% of inductance improvement is observed.

References:
RF Inductor with Patterned Permalloy Grids

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Figure 1, top right:
Top view of the 6-turn fabricated inductor.

Figure 2, below right:
SEM top view of the permalloy pattern with 2 µm wide permalloy bars and 2 µm spacing. The orthogonal 16 µm metal wires placed on top of the permalloy layer are also shown, and two layers are separated by a 0.3 µm PECVD oxide.

Figure 3, below left:
The extracted effective inductance (L) and the quality factor (Q) for 6-turn inductors with different permalloy patterns.