Characterization of Monolithic Coreless Transformers for Power Supply-on-Chip Applications‡

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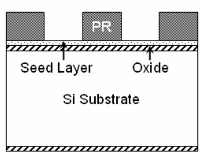
Introduction

- High frequency operations enables miniaturization and integration of transformers for power supply.
- Thin-film micro-transformers with core suffers from increasing core losses and magnetic-flux saturation at high frequencies.
- Coreless transformers would become more favorable at increasing frequencies.
  - No magnetic-flux saturation therefore no frequency limitation.
  - No hysteresis and core eddy-current losses.
  - Simple fabrication and clean-room compatible.

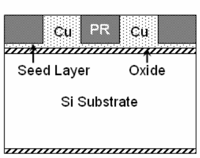
Design and Fabrication

- Monolithic coreless interleaved transformers are fabricated with different sizes (outer radius, R), number of turns (n), inner radius (r), track width (w) and spacing (s), track thickness (t) and substrate resistivity.
- Conventional LIGA UV fabrication processes are used

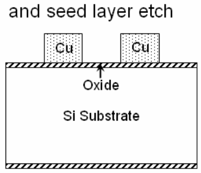
• Oxide deposition, seed layer sputtering and photolithography with 30um-thick photoresist AZ-4903



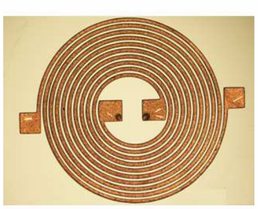
• Copper electroplating

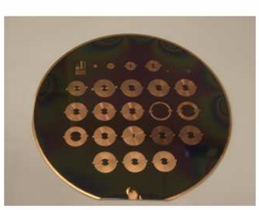


• Photoresist removal and seed layer etch



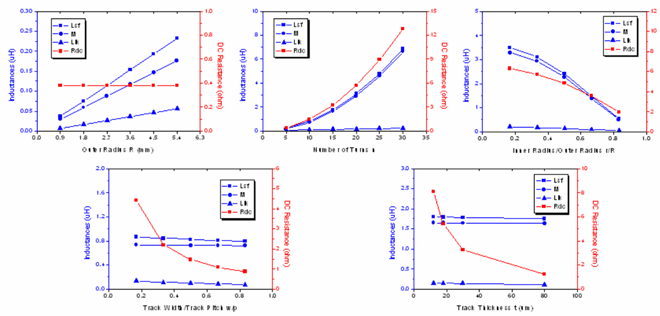
- Photos of the fabricated transformers are shown below:



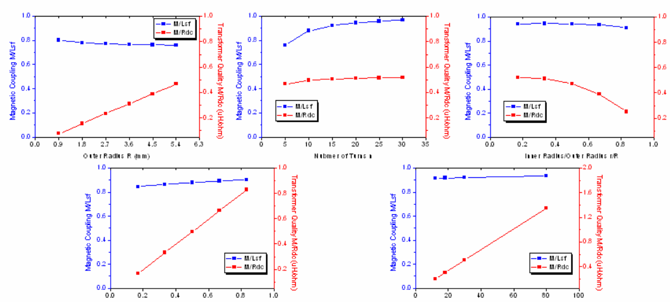


Simulation Results

- Dependence of self inductance (Lsf), mutual inductance (M), leakage inductance (Llk) and dc resistance (Rdc) on R (fix n and r/R), n (fix R and r), r/R (fix R, w, s), w/p (fix R, n, r and pitch p), and t (fix all else)



- Dependence of magnetic coupling (M/Lsf) and transformer quality (M/Rdc) on R, n, r/R, w/p and t.



- Lsf=1.28uH, M=1.23uH, Rdc=1.07ohm can be achieved for a transformer with R=3mm, n=20, t=80um, w=45um, and s=15um.

Conclusion

- Scaling down of transformer is at the cost of linearly reducing inductances while keeping dc resistance unchanged.
- Increasing track width and track thickness have little effect on inductances but reduces dc resistances inversely proportionally
- Increasing number of turns increases both inductances and resistances quadratically with magnetic coupling improved.
- Decreasing inner radius increases inductances faster than dc resistance.
- *For a certain frequency, decrease of inductances during transformer miniaturization has to be compensated by increasing number of turns. It requires narrow track width and spacing which increases the coil resistance. Track thickness has to be increased to keep resistance small.*

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