Micro-Fabricated Inductors with Nanocomposite Magnetic Cores for On-Chip Power Conversion

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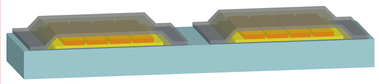
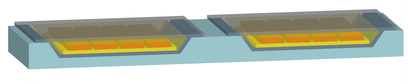
Introduction

- **Project goal:** Integrated magnetics for on-chip 25 W LED driver operating at 5-30 MHz
  - 10-100x size reduction
  - >3x reduction in energy losses
- Efficient and power dense magnetics achieved using racetrack inductor geometry with Co-Zr-O **nanocomposite magnetic magnetial:**
  - High saturation flux density (3x ferrite)
  - High resistivity (>10x NiFe)
  - Moderate permeability and strong anisotropy



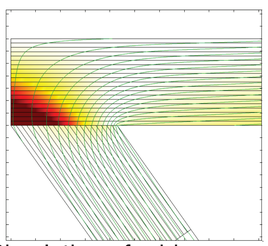
Surface racetrack inductor



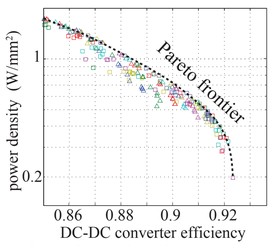
Silicon-emdedded racetrack inductor

- **Surface** and **embedded racetrack** inductors on silicon wafers can achieve:
  - High impedance (0.5 - 1.5 μH)
  - High power density (>1 W/mm²)
  - Minimal power loss through detailed modeling and optimization

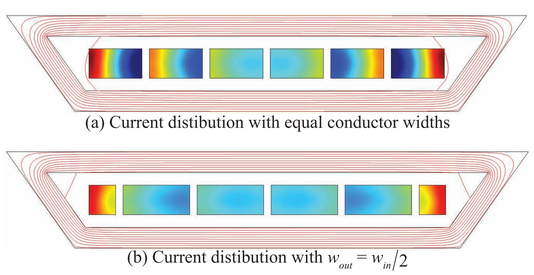
Modeling & Optimization



Simulation of eddy current loss in laminated cores

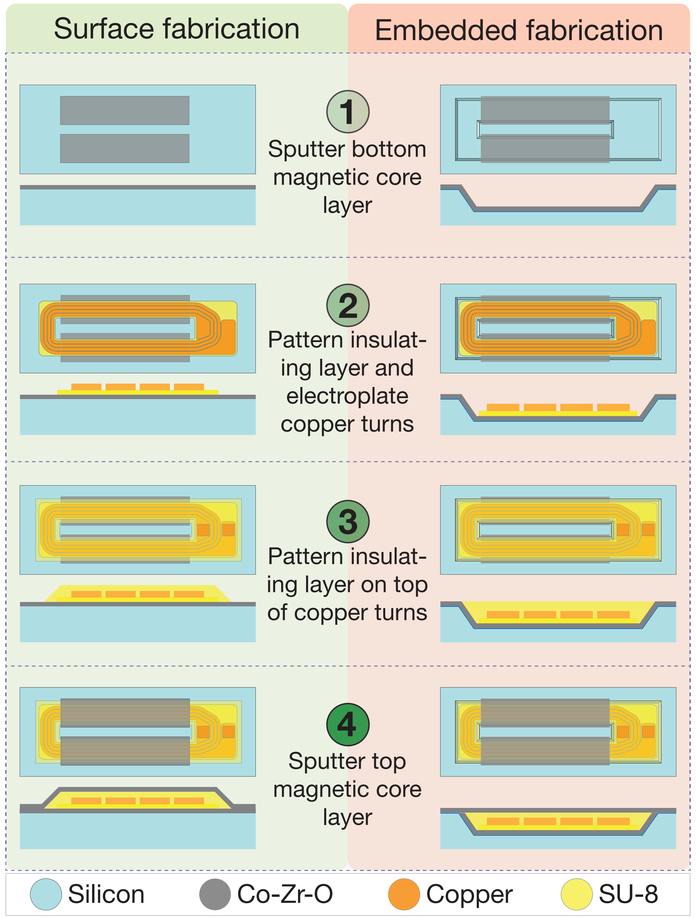


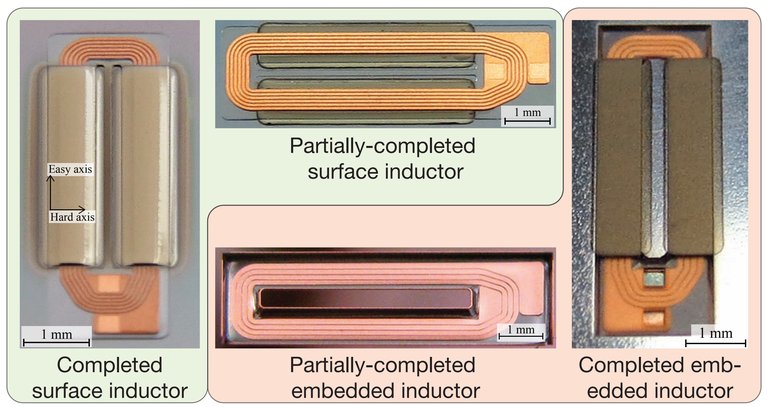
Pareto frontier of inductor designs found using particle swarm optimization



Simulation showing effect of decreased outer conductor width

Fabrication



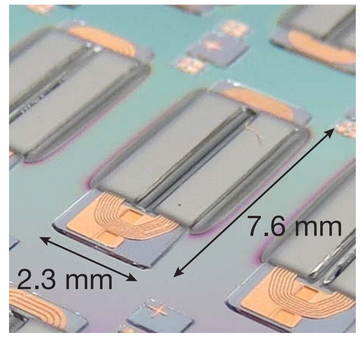


Cross section of a surface inductor

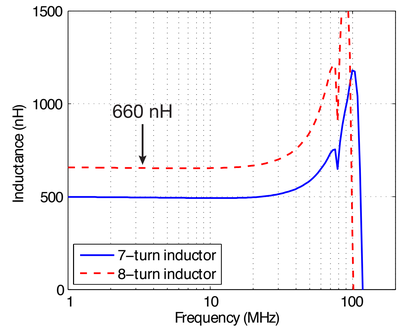
500 μm

Results

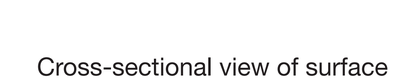
- Successful in-circuit operation: 10 MHz, 85% efficiency



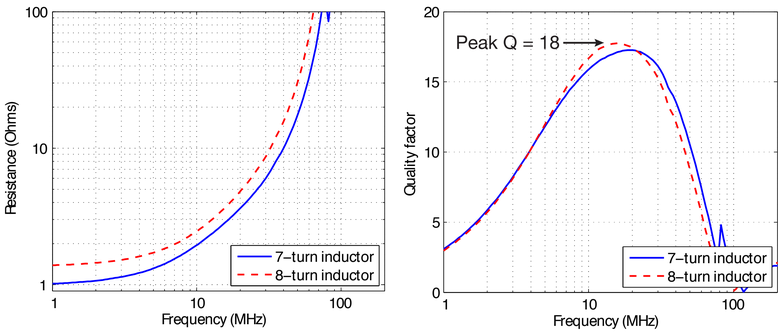
Completed surface inductor



Inductance versus frequency for 7 and 8 turn inductors



Cross-sectional view of surface inductor showing thin magnetic deposition along sloping sidewall resulting in lower impedance



Resistance and quality factor measurements versus frequency.

- Future inductors will have 2x thicker cores with uniform thickness, shorter magnetic path, and lower coil resistance

Further Reading

1. D.V. Harburg, et al. “Micro-fabricated Thin-film Inductors for On-chip Power Conversion.” In Proc. IEEE Conf. Integrated Power Electron. Sys. (CIPS), 2012.
2. D.V. Harburg, et al. “An Improved AC Loss Model for the Optimization of Planar-Coil Inductors.” In Proc. IEEE Control and Modeling for Power Electron. (COMPEL), 2012.