Air Gap Integration in Electrical Interconnections

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Acknowledgments

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Introduction

- There is a need for low dielectric constant (low-k) materials since shrinkage in transistor size causes propagation delays, crosstalk noise and power dissipation due to resistance capacitance coupling.
- Air-gaps provide the lowest effective dielectric constant available.
- Air-gap construction centers on use of a sacrificial polymer layer in fabrication.
Air-Isolation in Epoxy Boards

- Schematic of microstrip configuration with air-isolation.
- 50% reduction in capacitance proposed.
- Designed by Tae-Hong Kim, Graduate student in Georgia Tech School of Electrical Engineering.
Board Fabrication Process

AZ4620 Photoresist
17 um copper layer
FR4 Epoxy Board

Sacrificial Polymer (PPC)
17 um copper line
FR4 Epoxy Board

Sacrificial Polymer (PPC)
17 um copper line
FR4 Epoxy Board

Jet Coating Layer
17 um copper line
FR4 Epoxy Board

Ti-Cu-Ti Sputtered Layer
Air gaps
17 um copper line
FR4 Epoxy Board

Electroplated Cu
Air gaps
17 um copper line
FR4 Epoxy Board
Lines At Various Points in Fabrication Process

Before Electroplating Ground Line

Before Sputtering
Methodology

- A properly designed air gap will result in lower capacitance readings for the line.
- For a newly fabricated board, the capacitance was read prior to decomposing the sacrificial polymer and after.
- Reasons were sought for the measured values and variances from expected values.
Experimental Apparatus
Board on Probe Station
Test Board
Results

- There were three widths: 600 µm, 240 µm and 150 µm. Lines for which capacitance could be predicted were 58 mm long.
- Sixteen of 20 lines fabricated could be read.
- Atypical capacitance in a 600 µm width line read 11.597 pF before decomposition and 10.479 pF after decomposition, a 9.6 % reduction. The geometry and the Avatrel-polymer combination used projected a 14% reduction in capacitance.
- Overall, results were mixed: 600 µm line reductions ranged from 5-10%; 240 µm and 150 µm line capacitance increased. Possible explanation is sagging of lines after decomposition of the polymer layer.
- Capacitance on both test and practice boards tend to creep up over time.
Conclusion

The research goal is to show permanent and consistent statistically significant reduction in capacitance between interconnect lines by use of air gaps. More research will need to be done to:

• determine why capacitance creeps up over time and prevent this.

• determine the optimal Avatrel-polymer ratio.

• consider the role of additional support structures to prevent sagging of lines.
Lesson Plans

- The students will explore the variables that will affect capacitance of a parallel plate capacitor utilizing the relationship $C = kA/d$.
- Students construct a parallel plate capacitor and design an experiment to test how different variables in the equation $C = kA/d$ affect capacitance.
Lesson Plans

- The students will form groups and be given materials to make a capacitor and determine its capacitance.
- Using the capacitor the teacher will lead the class in a discussion on which variables affect capacitance.
- Each group will then devise an investigation to test the variables identified by the class.