Experimental Electrical Characterization of On-Chip Interconnects

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1 Introduction

This paper describes the transmission line and capacitance measurements made on a 0.25 micron test chip. Transmission lines were characterized to frequencies up to 20 GHz using a Hewlett Packard network analyzer and capacitances were determined using conventional capacitance meter. These measurements will help to develop benchmark capacitance and resistance values of on-chip interconnect structures. Measurements of the physical dimension of the interconnect structures will facilitate the determination of the effects of geometric assumptions made by capacitance extraction tools.

The IC test structure has three metal layers. Each structure was completely surrounded by guardbands to insure that it is well-isolated from other structures. The guardbanding consists of a ring of metal on each metallization layer; these rings were then be attached to each other and to the substrate using enough vias to guarantee a "good" ground.

Some structures were laid out at three different lengths; this is required for microwave measurement calibration. Raw measurements were made on a long line (with the suffix l, L=6400μm), a medium length line (with suffix m, L=800μm), and a short line (with suffix s, L=400μm). There were six different widths of the line viz., 0.25μm, 0.35μm, 0.45μm, 0.5μm, 0.6μm and 0.7μm. When there were more than one line in the structure, they are separated by a distance S. S can be either 0.45μm, 0.5μm, 0.6μm or 0.7μm. A large number of test structures were designed using various combination of these values. The complete measurement suite is available at http://www2.ncsu.edu/eos/project/erl_html/interconnect. In Section 3, an example of one measurement suite is described.

2 Measurements

Measurements were made using a coaxial prober from GGB Industries. The microprober used is shown in Figure 1, and a Hewlett Packard Automatic Network Analyzer (ANA) HP8510B connected to a HP workstation was used for data retrieval. There are two probes shown here; each has three contacts—a signal contact and two guard contacts. Coaxial probes (GGB model 40 picoprobes) were used which continue the coaxial probe to within 1 mm of the final test fingers. The guard contacts are extensions of the outer conductor of the coaxial line. On the chip, a set of three probe pads are contacted. The minimum dimension of the probe pads are 50 μm on one side with the outer pads typically connected to the chip ground. Sub-picofarad capacitance measurements require a balanced probe system, but the electrical balance must, of course, be disturbed at the probe, resulting in a residual capacitance. The residual capacitance of the microprobe and the probe pad is approximately 70 fF; this is subtracted out of the measurements. This establishes a resolution of 4 fF. Thus the resolution of the capacitance measurement is independent of that of the capacitance meter provided that the meter's resolution is 1 fF or less.

Capacitance measurements were made using conventional contacting probes and transmission line characterization was performed using a microwave network analyzer and microprobes. The Through Line Method was used for transmission line characterization as this minimized the area required for calibration structures. The measurement procedure is described in details in [1-3]. Physical Cross-Section Measurements measurements were made using a Scanning Electron Microscope.

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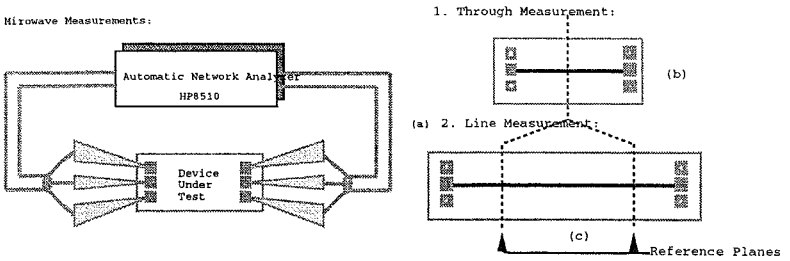


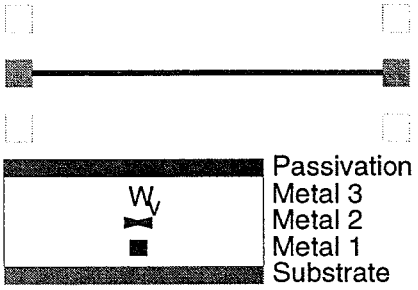
Figure 1: Set-up for microwave measurements: (a) test set-up using a Cascade Microtech probe station and picoprobes from GGB industries.

3 An Example

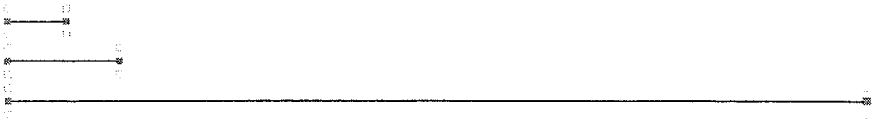
This section details one of the test structures that was measured using conventional mechanical probing techniques. The structure was laid out at three different lengths; this is required for microwave measurement calibration. Raw measurements were made on a long line (with the suffix l, L=6400μm), a medium length line (with suffix m, L=800μm), and a short line (with suffix s, L=400μm). All derived parameters are reported for two extractions designated by the source of the raw data. Extractions with the suffix ls (or l,s) were extracted using the long and short lines. Extractions with the suffix lm (or l,m) were extracted using the long and medium lines. Next page shows the plan view, cross section view, three instances along with SEM images of the structure.

Plan View:

Cross-Section:



Instances:



References

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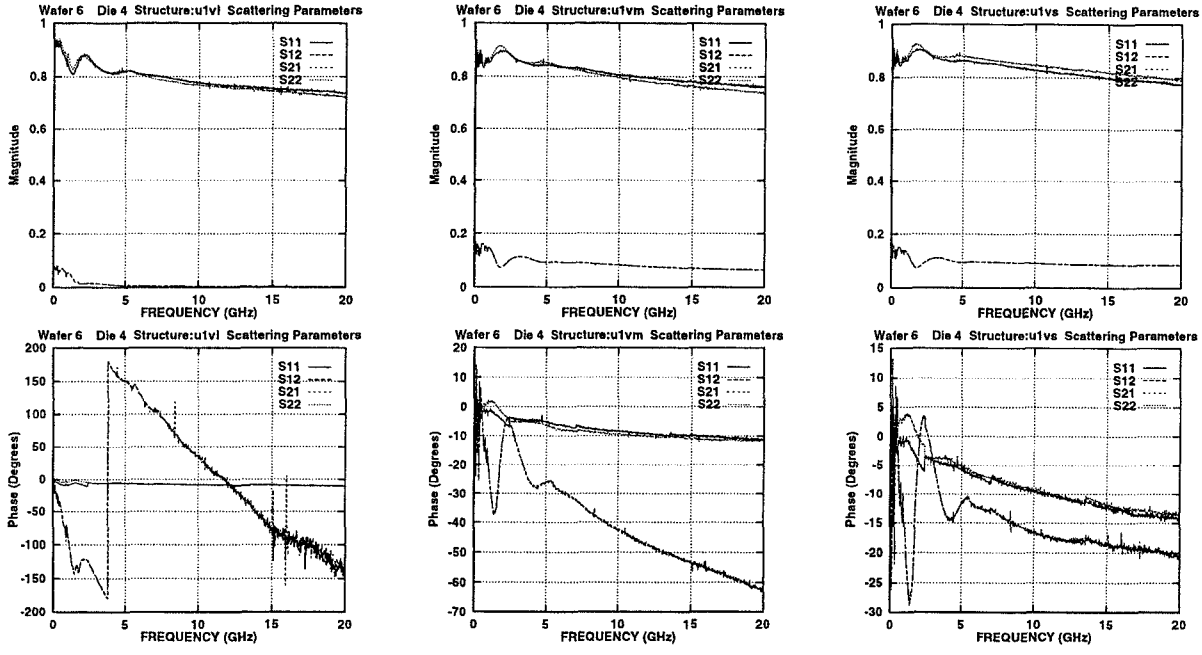
2. S. Lipa, M.B. Steer, A.S. Morris, and P.D. Franzon, "Comparison of methods for determining the capacitance of planar transmission lines with application to multichip module characterization," *IEEE Trans. on Components Hybrids and Manufacturing Technology, Part B: Advanced Packaging*, Vol. 16, May 1993, pp. 247-252.

3. S.B. Goldberg, M.B. Steer, P.D. Franzon and J.S. Kasten, "Experimental electrical characterization of interconnects and discontinuities in high speed digital systems," *IEEE Trans. on Components Hybrids and Manufacturing Technology*, Vol. 14, December, 1991, pp. 761-765.

Measured raw scattering parameters of long (l), medium length (m) and short (s) lines.



Derived data. l,s using long line and short line. l,m using long line and medium length line.