Novel 5X-Line Technique to Extract Copper Conductivity

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This paper proposes a new characterization technique to extract parameters crucial for calculating the bulk conductivity of copper on printed circuit boards. The 5X-Line technique extracts the final processed sheet resistance, line width, frequency dependent resistance, and inductance of the copper traces on the printed circuit boards. As low loss substrates are readily available and used in industry, conductor loss becomes a main contributor to overall loss. Without knowing the bulk conductivity of copper, conductor loss cannot be accurately predicted and modeled.

Although the conductivity for pure copper is well known, there is no consistent value for processed copper on circuit boards. In fact, the conductivity of processed copper might vary across a board, from board to board, and from manufacturer to manufacturer. As a prelude to extracting intrinsic bulk conductivity, this new technique separates out the sheet resistance and etch back factors from fabricated signal lines on any layer in a multilayer board. The DC resistance of multiple line widths is measured and the sheet resistance and etch back or over plate factors are fitted to the results.

This monitoring of the variation in sheet resistance of as-fabricated copper traces on each layer of the board allows us to track variations from the plating processes and from the etching processes. This technique is used to evaluate the copper sheet resistance from layer to layer and from board to board.

The same test lines can be measured with both DC techniques and RF techniques. As part of a longer term study of the copper electrical properties, RF techniques using network analyzer measurements are used to measure the frequency dependent resistance and inductance of traces on different layer. At low frequency, below the skin depth effect, the DC resistance and RF resistance are measured and correlated, establishing the bridge between the accuracy of these two very different techniques.

The RF technique is extended from low frequency into the GHz regime to extract the frequency dependence of the resistance and inductance. This RF technique relies on a novel 2-port fixture and interpretation of the S-parameters to extract very low impedance. Along the way a few important artifacts have been identified and eliminated.

Correlation of DC and RF measurement suggests that the novel 5X-Line technique is a robust process to obtain sheet resistance and frequency dependent resistance for the calculation of bulk resistivity