A New Prognostic Tool for TSV Reliability Assessment Using RF Signals

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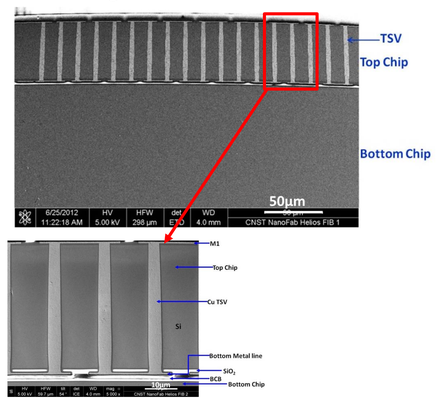
Objective

To assess the suitability of RF-based measurement technique as a metrology tool for studying the reliability performance of through-silicon via (TSV).

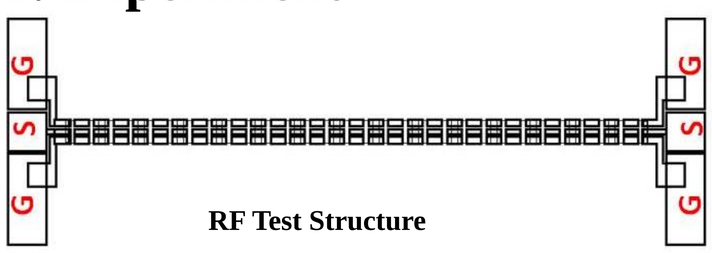
1. Why Use RF-Based Technique?



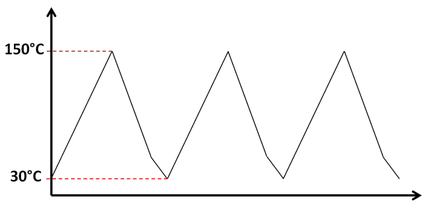
Stacked Die

- Reliability analysis over broad frequency ranges
- Sensitivity to discontinuities in and around conductive paths; metals, dielectrics, semiconductors
- Measurement of both reflected and transmitted signals
- High sensitivity to the presence of defects

2. Experiment



RF Test Structure



Temperature Cycling Profile

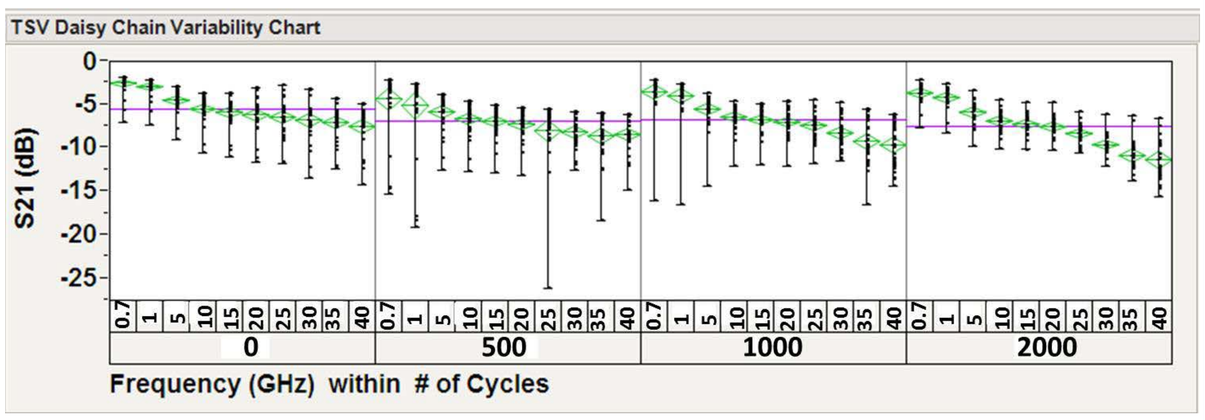
RF Test Structure

- Ground-Signal-Ground (GSG) configuration.
- Daisy chain of 60 TSVs
- 34 die samples analyzed

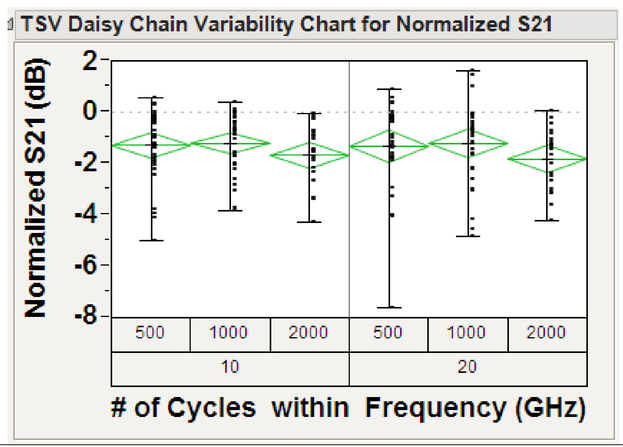
Experiment

- 1 cycle = 5.5 min
- Two port S-parameter measurement: 500 thermal cycles intervals
- Physical failure analysis: FIB and TEM techniques

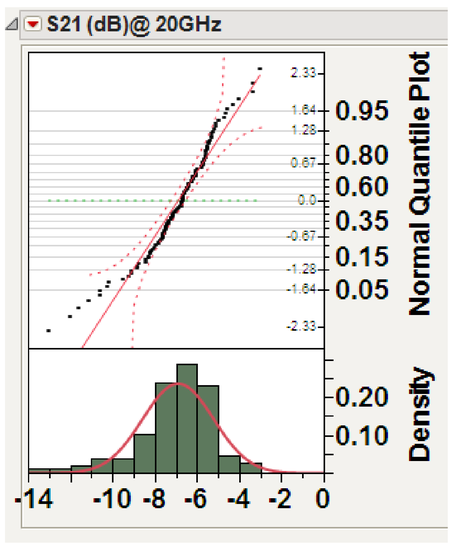
3. RF-Based Results



- Statistical analysis based on 34 dies show that at 20 GHz and below, that the maximum insertion losses occurs after initial 500 cycles and after 2000 thermal cycles.

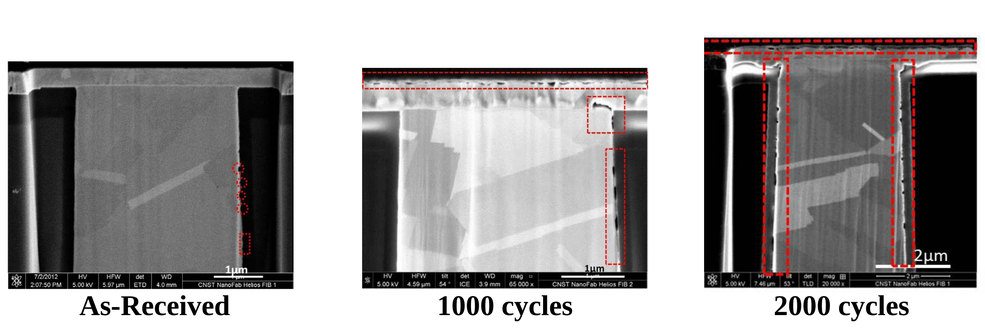


- The normalized graph show similar trend as previous graph. At 10 and 20 GHz, no main appreciable difference in RF signal characteristics between 500 and 1000 cycles.
  - Degradation of RF signal characteristics attributed to the initiation and growth of defects.



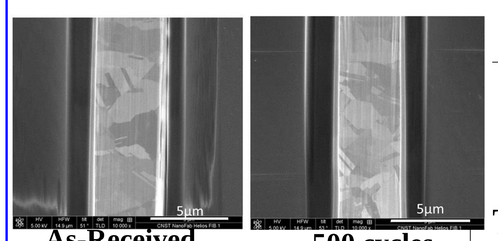
- Data distribution is not a normal distribution, which suggests multiple root causes for RF signal degradation.

4. FIB Based Results



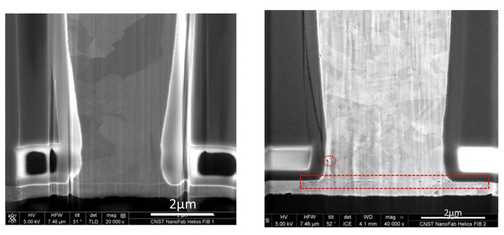
As-Received **1000 cycles** **2000 cycles**

- Void formation at TSV –TaN interface
  - Increases with # of thermal cycles
- TSV-M1 voids linkup with TSV-TaN voids
- M1 void propagation upon thermal cycling

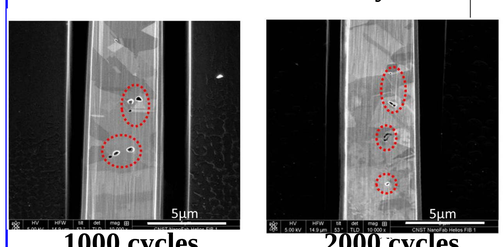


As-Received **500 cycles**

No significant voiding in TSV central region



As-Received **500 cycles**



1000 cycles **2000 cycles**

- Void propagation at the TSV-Bottom metal line interface upon thermal cycling

5. Conclusions

- RF-Based technique is an effective method for the assessment of TSV reliability.
- Thermal cycling leads to the degradation of RF signal characteristics of TSVs.
- The degradation of TSV RF characteristics with thermal cycling is associated with the formation and growth of voids.

Reference: C. Okoro, P. Kabos, J. Obrzut, K. Hummler, Y. S. Obeng, "Accelerated Stress Test Assessment of Through-Silicon Via Using RF Signals," IEEE Trans. on Electron Devices. In Review