A Novel Cu/CNT Material System for Through Silicon Via Interconnects

NSF CMMI 1234652

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Background and Objectives: Interface resistance, electrical and mechanical integrity of CNTs and other metallic materials have been the main barriers in adapting CNTs in electronic and semiconductor industry. We propose to use several novel techniques to enhance mechanical and electrical functionality of CNTs in microelectronics at the interface with metallic interconnects. The project objectives are:

- To experimentally explore the possibility of fabricating a hybrid material system consisting of CNTs and copper that can be used in the next generation TSV interconnects.
- Examine possibility of enhancing the electrical and mechanical integrity of these interconnects using different advanced techniques such as molecular anchoring and elastocapilary densifications.
- Examine the mechanical and electrical integrity of the new interconnects through multi-scale simulation and experiments

Project Approach:
The project consists of design and fabrication of highly oriented, highly dense conductive CNTs inside blind vias, encasing them with copper material using electroplating of copper, chemical-mechanical polishing of backside of wafers and electroplating of copper to make daisy chain interconnects. These interconnects are then subjected to different types of mechanical and electrical experiments to examine their mechanical and electrical integrity. Interface of CNTs and copper material is the most problematic area and mechanical and electrical integrity of CNTs and copper is questioned at this interface. Multi-scale finite element simulation is used to obtain the local interfacial properties through molecular dynamic (MD) simulation and determine the stresses at the interface of the CNT bundle and copper at larger scale. This modeling is also used to determine the strains and stresses developed during the mechanical testing at different location on the test coupons. These results are used in conjunction with experiment to determine the long term reliability of these interconnects.

Notable Discoveries:
- SWCNTs were successfully grown inside blind through silicon vias and the resulting structures could be effectively electroplated by copper.
- The pillars can also be densified and the resulting pillars show a densification factor of approximately two. The densified CNT pillars were also successfully copper electroplated.
- From MD simulation, increasing the number of CNTs in contact with copper increases the pull-out force linearly. This relationship can be used to predict the total pull out force for a bundle of CNTs.
- Adding interior CNTs which are not in contact with Cu, will decrease the strength of the interface.
- Embedded length has no effect on the average pull-out forces. Only oscillations amplitudes

increases because of (stick-slip) behavior.