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Investigation of carbon nanotube as the filling material for integrated circuit contacts and vias

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Project summary

Based on the ITRS (International Technology Roadmap), the integrated circuit feature size has been shrinking rapidly. The contact and via are usually the smallest and most abundant features in an integrated circuit. The performance as well as the yield of the integrated circuit depends heavily on the robustness of the contact and via technology. CNT can potentially provide a very small yet highly conductive and reliable contact/via filler for integrated circuits. The objective of this project is to investigate the feasibility of using CNT for integrated circuit contact/via filler.

Different sizes vias from 1 μm to ~100 nm fabricated by optical lithography and E-beam lithography were studied under different conditions. We developed a method to integrate the Cu/CNT composite as via filling material. A summary of the fabrication process is illustrated in Fig. 1. This integration scheme is compatible with current Cu interconnect technology. The physical and electrical properties of the contact between carbon nanotube and metal layers were studied. The recipe for multi-walled carbon nanotube (MWCNT) vertical growth, and novel test structures were investigated. Figure 2 shows the *I-V* curves of the Cu/CNT composite via and the CNT via measured using two-via-chain structure. We found that the copper filled CNT vias have superior resistance to electromigration over industry standard copper vias. The performance enhancement can be attributed to the large contact area established between CNT and metal, as well as the more conductive channels provided by filling the voids with Cu. Many electron injection pathways were established between the CNT and metals. One CNT per via configuration was also demonstrated in this project.

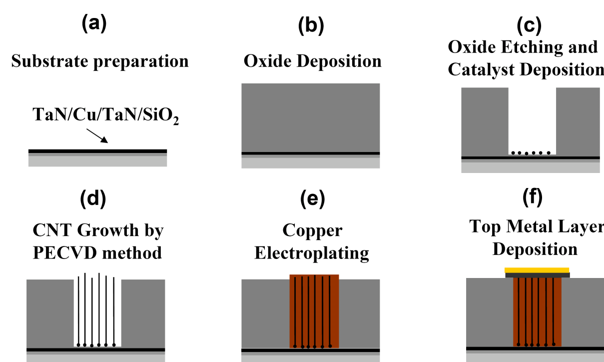

Figure 1

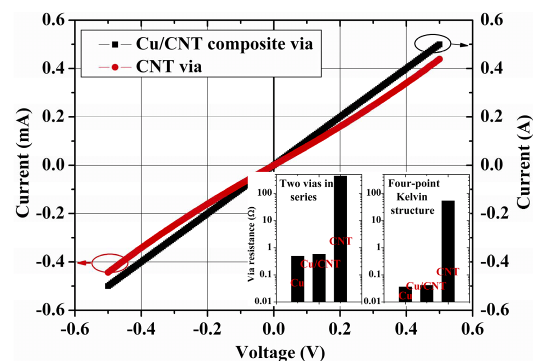

Figure 2

Peer reviewed journal publications:

J1. *Yang Chai, Jingfeng Gong, Kai Zhang*, Philip C. H. Chan, and Matthew M. F. Yuen, "Flexible Transfer of Aligned Carbon Nanotube Films for Integration at Lower Temperature", Nanotechnology, 18, pp. 35-39, 7 August 2007.

J2. *Yang Chai*, Philip C. H. Chan, *Yunyi Fu*, Y. C. Chuang and C. Y. Liu, "Electromigration Studies of Cu/Carbon Nanotube Composite Interconnects Using Blech Structure", IEEE Electron Device Letters, pp. 1001-1003, Vol. 29, No. 9, 2008.

J3. *Yang Chai, Zhiyong Xiao*, Philip C. H. Chan, "Electron-Shading Effect on the Horizontal Aligned Growth of Carbon Nanotubes Using Plasma-Enhanced Chemical Vapor Deposition", Applied Physics Letters, 94, 043116 (2009), January 2009

J4. *Yang Chai, Zhiyong Xiao* and Philip C. H. Chan, "Low-Resistance Carbon Nanotube Contact Plug to Silicon", pp.811-813, Vol. 30, No.8, IEEE Electron Device Letters, August, 2009.

Peer reviewed conference publications:

C1. *Yang Chai, Kai Zhang, Min Zhang*, Philip C. H. Chan and Matthrew M. F. Yuen, "Carbon Nanotube/Copper Composites for Via Filing and Thermal Management", pp.1224-1229, 57th Electronic Components and Technology Conference, ECTC, May 29-June 1, 2007, Reno, Nevada, USA.

C2. *Yang Chai, Jingfeng Gong, Kai. Zhang*, Philip C. H. Chan and Matthrew M. F. Yuen, "Lower Temperature Transfer of Aligned Carbon Nanotube Films Using Liftoff Technique", pp. 429-434, 57th Electronic Components and Technology Conference, ECTC, May 29-June 1, 2007, Reno, Nevada, USA.

C3. *Yang Chai*, Philip C. H. Chan, *Yun-Yi Fu*, Zhuo-Qun Zhuang and Cheng-Yi Liu, "Copper/Carbon Nanotube Composite Interconnects for Enhanced Electromigration Resistance", pp. 412-420, 58th Electronic Components and Technology Conference, ECTC, June 2008, Orlando, USA.

C4. Philip C. H. Chan, *Chai Yang, Min Zhang, Yunyi Fu*, "The Application of Carbon Nanotubes in CMOS Integrated Circuits", pp. 534-536, 9th International Conference Solid-State and Integrated Circuit Technology (ICSICT), Beijing, China, October 2008 (invited plenary paper).

C5. *Yang Chai*, Philip C. H. Chan, "High Electromigration-Resistant Copper/Carbon Nanotube Composite for Interconnect Application", pp. 607-610, International Electron Device Meeting (IEDM), San Francisco, CA, USA, Dec. 15-17, 2008.

C6. *Yang Chai, Zhiyong Xiao* and Philip C. H. Chan, "Fabrication and Characterization of the Horizontally Aligned Carbon Nanotubes for the Interconnect Application", pp.1465-1469, IEEE Electronic Components and Technology Conference (ECTC), May 26-29, 2009, San Diego, USA.

C7. *Zhiyong Xiao, Yang Chai,* Philip C. H. Chan, "Sacrificial Removal of Caps of Aligned Carbon Nanotubes for Interconnect Application", pp. 1181-1185, IEEE Electronic Components and Technology Conference (ECTC), May 26-29, 2009, San Diego, USA.