GROWTH AND CHARACTERIZATION OF VERTICALLY ALIGNED CARBON NANOTUBES FOR INTERCONNECT APPLICATIONS

By

Dingyou Zhang

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Major Subject: ELECTRICAL ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Approved:

James Jian-Qiang Lu, Thesis Adviser

Rensselaer Polytechnic Institute
Troy, New York

July 2010
(For Graduation August 2010)

Following Moore's Law, the number of transistors integrated in a microprocessor has been increasing constantly by scaling down the feature sizes. With the technology scaling, the interconnect latency and the interconnect current density increase. To mitigate these interconnect issues, copper has been introduced to replace the aluminum as the interconnect material in the manufacture of IC chips since 180 nm technology node because copper has some significant advantages over aluminum, such as lower resistivity, higher melting point and better electromigration resistance, resulting in longer median time to failure and higher current density capability.

However, copper resistivity increases rapidly with the decrease of copper wire width below 100 nm. This resistivity increase results in an increase of copper interconnect latency, which has become a very difficult problem for further technology scaling. Since this resistivity increase is a fundamental problem, new materials have been searched to replace the copper.

Due to its superior electrical, thermal and mechanical properties, carbon nanotube (CNT) is seen as one of the closest possible replacements to copper, providing a substantially higher resistance to electro-migration and hence fewer failures. Theoretical studies disclose that densely packed CNT bundle interconnects should have a lower interconnect latency than copper interconnects. However, CNT bundles produced by three main methods so far have some critical limitations for use as an interconnect material. Arc discharge and laser ablation methods for CNTs growth require extremely high temperature (>3,000 °C). It is difficult to grow uniform CNTs in large wafer-scale using traditional chemical vapor deposition (CVD) furnace.

Limitations of existing CNT growth methods drive the need to invent new CNT growth methods. A novel rapid thermal processing method for vertically aligned CNTs growth is demonstrated in this thesis. Influences of heating rate, processing time, growth temperature, catalysts and other factors on CNT growth by RTP method are investigated systematically. Optimal processing parameters for vertically aligned carbon nanotube growth by rapid thermal processing are presented as a guideline. This rapid thermal processing method provides (1) a good control on temperature profile, which is critical for CNT growth, (2) fast heating rate, which helps for CNT growth and alignment and (3) a potential opportunity for CNT growth on wafer level.

This work provides a new solution to grow vertically aligned CNTs using a potentially scalable process, with a controllable temperature profile and a fast heating rate, which brings us closer to the realization of CNT interconnects.