Task ID: 425.020
Task Title: An Integrated, Multi-Scale Framework for Designing Environmentally-Benign Copper, Tantalum and Ruthenium Planarization Processes

Deliverable: Report on the evaluation of environmental issues in slurry chemistries for emerging/novel materials, e.g. ruthenium.

I. Summary/Abstract.

This report summarizes recent literature search results of slurry chemistries for ruthenium CMP process and related environmental, health, and safety issues.

II. Technical Results and Data.

Ruthenium (Ru) has been suggested as an alternative barrier layer for copper interconnect used in the IC manufacturing industries, due to its excellent electrical performance, including a low leakage of current, compatibility with high dielectric constant materials, good electrical conductivity, immiscibility with copper, and good adhesion property to copper layer [1].

A literature search was performed to illustrate the recent development in slurry chemistries for Ru CMP and related environmental, health, and safety issues. Being a noble metal, Ru is chemically very stable. Therefore, the hydrogen peroxide based chemistries used for other common metal CMP processes, such as copper, tantalum / tantalum nitride, and tungsten, do not generate satisfactory removal rates for Ru CMP. In recent studies [2-5], sodium periodate ($NaIO_4$) and ceric ammonium nitrate ($(NH_4)_2Ce(NO_3)_6$)-containing nitric acid have been used as the oxidizer in slurries for Ru CMP process. For both oxidizers, ruthenium dioxide (RuO_2) is formed as the passivation film and then further oxidized to ruthenium tetroxide (RuO_4). Ruthenium tetroxide is very soluble in water and forms hyper-ruthenic acid (H_2RuO_5).

In general, all ruthenium compounds are regarded highly toxic and carcinogenic. Compounds of ruthenium stain skin very strongly. Ruthenium tetroxide is considered as an explosive compound [2]. Therefore, ruthenium tetroxide must be removed or otherwise prevented from building to dangerous levels. It should also be noted that ruthenium tetroxide in the gaseous phase is more hazardous as it can be easily inhaled by humans working in the proximity of the chemical and cause serious harm. Therefore, it is critical to prevent ruthenium tetroxide to enter gaseous phase during the CMP process.

III. Reference

[1] In-Kwon Kim, Tae-Young Kwon, Jin-Goo Park, and Hyung-Soon Park. Development and Optimization of Slurry for Ru CMP. Materials Research Society Symposium Proceedings, Vol. 991, 0991-C10-04, 2007.

[2] Donald L. Westmoreland. Ruthenium and ruthenium dioxide removal method and material. United States patent publication No. US2002/0056829.

[3] Woo Jin Lee. Solution for ruthenium chemical mechanical planarization. United States patent 6,797,624 B2.

[4] Woo-Jin Lee and Hyung-Soon Park. Development of novel process for Ru CMP using ceric ammonium nitride (CAN)-containing nitric acid. Applied Surface Chemistry, Vol. 228, 410-417, 2004.

[5] In-Kwon Kim, Young-Jae Kang, Tae-Young Kwon, Byoung-Gwun Cho, Jin-Goo Park, Jum-Yong Park and Hyung-Soon Park. Effect of Sodium Periodate in Alumina-Based Slurry on Ru CMP for Metal-Insulator-Metal Capacitor. Electrochemical and Solid-State Letters, Vol. 11, H150-H153, 2008.