Task ID: 425.021
Task Title: Low Water and Low-Energy Rinsing and Drying of Patterned Wafers, Nano-Structures, and New Materials Surfaces
Deliverable: Report on the reliability of the Electrochemical Residue Sensor (ECRS)

Summary/Abstract:
The primary objective of this work is to determine ways in which DI water usage in rinse processes can be reduced without sacrificing overall wafer cleanliness. In order to meet that objective, a novel electrochemical sensor was developed for in situ and real-time measurement of the residue contaminations inside micro/nano structures. Also a theoretical study has been performed to transfer the sensor's reading to the temporal contamination profiles in the trenches and vias. The theoretical model developed could also be used as a parametric study tool for process optimization. Recently, collaborations were set up with Freescale and others to test this new metrology technology in the production Fabs. Therefore, some modifications of the sensor and some robust tests have been performed to make sure the sensor can be used in the exact production conditions.

Technical Results and Data:

Preparation of the sensor:

The polysilicon sensor wafer was put into a piranha solution (2:1 sulfuric acid: hydrogen peroxide at 130 °C) to strip the remaining photoresist from the wafer fabrication. The residue chemicals were removed by a UPW rinse. A BOE (6:1) etch then opened the contact pads, gluing the connecting wires to the contact pads by using the silver epoxy made the electrical contacts. After the epoxy was fully cured, a layer of silicone was applied to cover all the contacting areas to form the insulation and protection.

Initial test:

The first test was the air test. In this test, a frequency sweep of the sensor was performed at room temperature while the sensor was hung in the atmosphere. The results listed in the Table 1 show that the sensor was well fabricated.

Table 1: Air test results

Frequency (Hz)	IZI (Ω)	Angle (degree)
1000	13650000	-90.0
10000	1522150	-88.5
100000	144870	-87.8
1000000	15813.5	-72.8

(Integration time: Med; Voltage: 0.1volt on HP 4284A precision LCR meter)

The second test was the UPW test. This test is the same as the air test except that the sensor was immersed in UPW. These results are shown in Table 2. These two tests were the starting point of all the experiments.

Table 2: UPW test results

Frequency (Hz)	IZI (Ω)	Angle (degree)
1000	98613.6	-60.394
10000	41319.2	-28.344
100000	17643	-44.205
1000000	5887.39	-20.618

(Integration time: Med; Voltage: 0.1volt on HP 4284A precision LCR meter)

Room temperature chemicals test:

In the room temperature chemicals test (RTC test), room temperature chemicals were used to be on the safe side. The sensor was immersed in room temperature chemicals for 10 minutes and then transferred to a hot water bath. The hot water bath was set up in a recirculating tank (the water in this tank is not refreshing or is refreshing at an extremely slow rate). The water temperature was set to be 80 °C to meet the industrial routine. After the sensor was kept in the hot bath for a preset time (10 min to 4 hours), the sensor was then transferred to a rinse tank at room temperature and a frequency sweep was performed while the sensor was in UPW. After the frequency sweep the sensor went back to a chemical bath, and the same procedures were performed again and again in 9-hour segments (8:00am to 5:00pm) to test the reliability of the sensor. The frequency sweeps in room temperature UPW at the end of these tests are shown in Fig. 1. and Fig. 2. The SC-1 is the same 1:1:5 SC-1 mixture but at room temperature. SC-2 is the 1:1:6 standard mixture at room temperature.

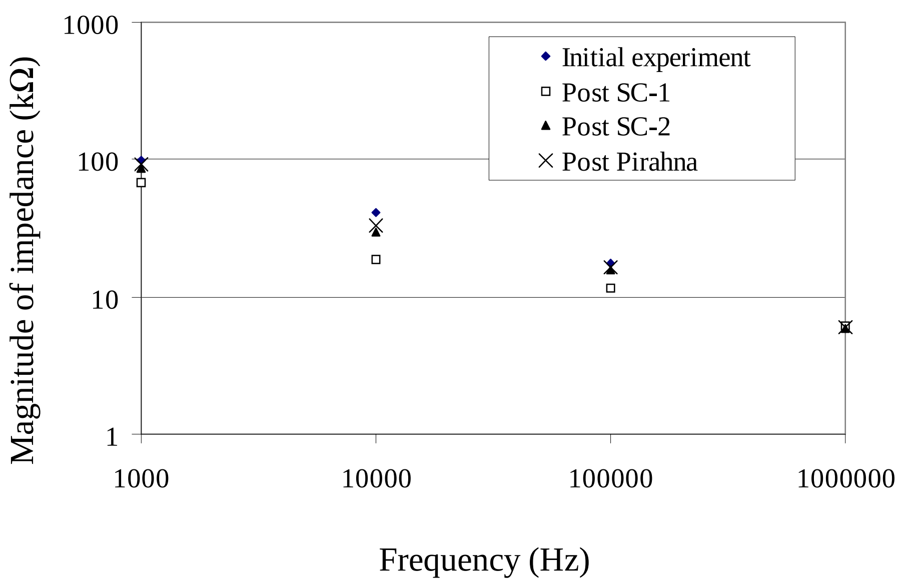

Fig.1: Sensor readings (Magnitude) after the cold chemicals and hot rinses

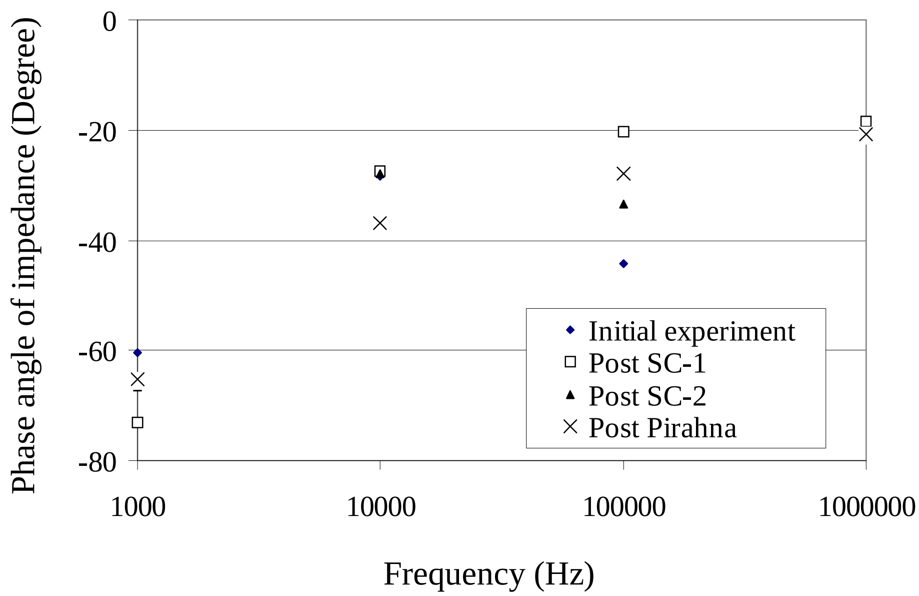

Fig.2: Sensor readings (Phase angle) after the cold chemicals and hot rinses

The experiment results in Fig. 1 show that the impedance does not significantly change after cold chemicals and rinses, which shows a good repeatability of the measurement. The phase angles in Fig. 2 also show the change from the capacitive behavior to the resistive behavior of the system, which indicates that there is no short circuit damage nor open circuit damage. The non-significant difference between the different experiments may come from different levels of contamination that were left in the sensor. Therefore, it is safe to say that the sensor is reliable for cold chemicals baths followed by hot baths.

Hot chemicals test:

The hot chemicals tests (HC tests) follow the same procedures as the room temperature chemicals tests except that the chemicals mixtures are heated to the industrial routine temperature. Piranha is kept at 125-140 °C; SC-1 and SC-2 are at 70-80 °C. The frequency sweeps in room temperature UPW at the end of the 9-hour experiments are shown in Fig. 3 and Fig. 4. A few piranha tests were performed because piranha was believed to be the harshest chemical in the wet clean process. Only two experiment sets' data of piranha clean are shown in the following figures.

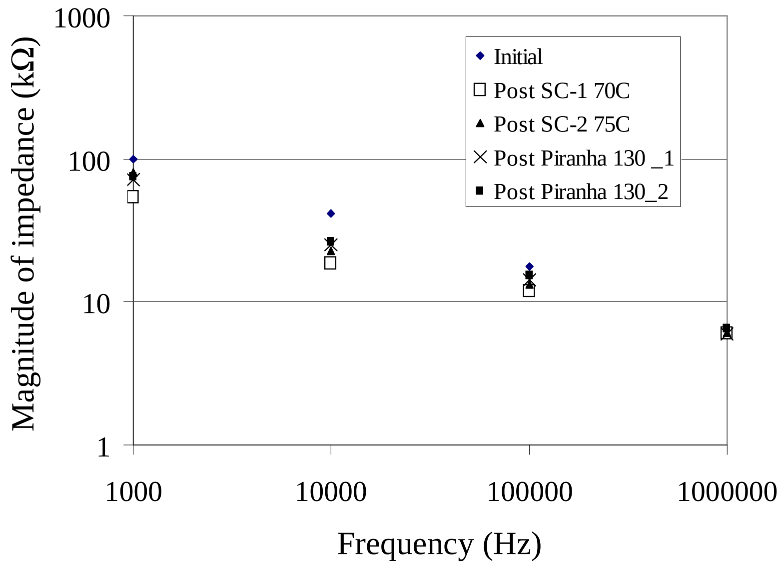

Fig.3: Sensor readings (Magnitude) after the hot chemicals and hot rinses

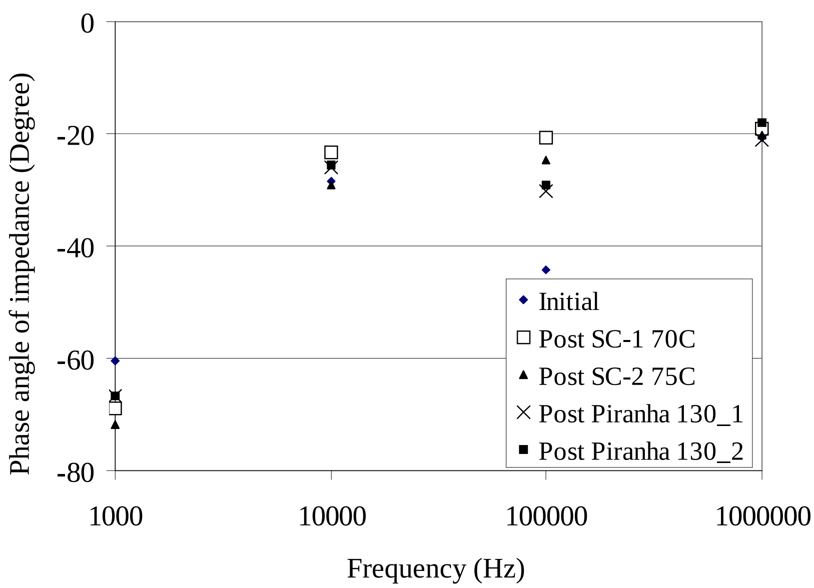

Fig.4: Sensor readings (Phase angle) after the hot chemicals and hot rinses

The hot chemicals tests results also show that the sensor is reliable in the hot chemicals when followed by hot water rinses, which mimics industrial operational conditions. Although there are small differences in these frequency curves, the repeatability of the measurement is acceptable at current experimental conditions.