INFLUENCE OF THE CLEANING PROCEDURE ON THE SURFACE ROUGHNESS OF SILICON WAFERS

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The search for high performance MOS devices with reduced dimensions requires ultrathin gate oxides with high breakdown dielectric fields and low density of interface states[1-3]. Such parameters are directly dependent on the Si/SiO_2 interface roughness, which should be as smooth as possible[1,4]. Nowadays, it is required pre-oxidation cleaning strategies[5,6] in order to control the surface topography. In this work, several chemical cleaning procedures were investigated having as focus the surface roughness.

Silicon wafers, 3 inches in diameter, with <100> crystalline orientation, (381± 50) μm thick, p-type and resistivity in the range of 1 to 10 Ωcm, were used. Atomic Force Microscopy (AFM) was used to map the surface topography. In the first set of experiments, as-received wafers were initially submitted to different cleanings in $4H_2O$:$1H_2O_2$: **z**NH_4OH during 15 min at 71°C or 84°C for **z** varying from 0.25 to 5. As a result, for that range of **z**, the surface average roughness varied from 0.065 nm to 0.104 nm. This is to say, the higher the value of **z** the higher the average roughness of the native oxide, which grows on the surface after cleaning. Following, the native oxide was removed in diluted HF (DHF: dip in $20H_2O$:1HF during 100s) and an approximately constant average roughness (≈ 0.060nm) lower than that in the range previously mentioned above was observed.

A second set of experiments consisted of several cleaning procedures having the following RCA[5]/DHF basic steps: ***i)*** Immersion in $4H_2O$:$1H_2O_2$:**x**NH_4OH at 80°C for 15 min; ***ii)*** rinse with deionized water during 5min (DIWR); ***iii)*** Immersion in $4H_2O$:**y**H_2O_2:1HCl at 80°C for 15min; ***iv)*** DIWR; ***v)*** DHF (optional); and ***vi)*** DIWR (optional). In addition, reverse RCA[6]/DHF was also performed as follows: ***i)*** Immersion in $4H_2O$: **y**H_2O_2:1HCl at 80°C for 15 min; ***ii)*** DIWR; ***iii)*** DHF; ***iv)*** DIWR; ***v)*** Immersion in $4H_2O$:$1H_2O_2$:**x**NH_4OH at 80°C for 15min; ***vi)*** DIWR; ***vii)*** DHF (optional); and ***viii)*** DIWR (optional). Table 1 shows the parameters **x** and **y**, which were used for all the cleaning procedures (CP1 – CP6), including the optional dip in diluted HF (DHF) and the RCA type.

Figure 1 shows the surface average roughness for a typical as-received wafer (L0) and for all the cleaning procedures. It was observed that CP1 and CP2 induces an increase of the roughness even after dipping in DHF compared to the first set of experiments. This means that the cleaning in $4H_2O$:$1H_2O_2$:1HCl solution can be made responsible for the increase of the average roughness of the surface silicon, which had the native oxide removed.

In contrast, the wafers which were cleaned with procedure 3 (CP3) presented the lowest average roughness after a final dip in diluted HF and having y = 0. Therefore, the hydrogen peroxide, present in the H_2O/H_2O_2/1HCl solution, is the chemical that induces the increase of the average roughness. The cleaning procedure 4 (CP4) has the same steps of CP3 except the final dip in DHF. In this case, the average roughness was higher than that obtained for wafers cleaned with CP3 (i.e., after native oxide removal).

Cleaning procedures 5 and 6 corroborate that it is the hydrogen peroxide, present in the H_2O/H_2O_2/1HCl solution, the chemical that induces the increase of the average roughness even in reverse RCA.

In conclusion, pre-oxidation cleaning procedures based on RCA/DHF were presented. The lowest surface average roughness is achieved if the content of ammonium hydroxide is diminished in the $H_2O/H_2O_2/NH_4OH$ solution, the hydrogen peroxide is removed from the H_2O/H_2O_2/1HCl solution and a final dip in diluted HF is performed. Hydrogen peroxide, present in the H_2O/H_2O_2/1HCl solution, was the main responsible for the increase of the average roughness of silicon wafers after RCA/DHF cleaning.

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	x	**y**	DHF	RCA
CP1	1	1	Yes	Normal
CP2	0.25	1	Yes	Normal
CP3	0.25	0	Yes	Normal
CP4	0.25	0	No	Normal
CP5	0.25	1	Yes	Reverse
CP6	0.25	1	No	Reverse

Table 1. Values of **x** and **y**; specification of final DHF (Yes or No) and type of RCA (Normal or Reverse).

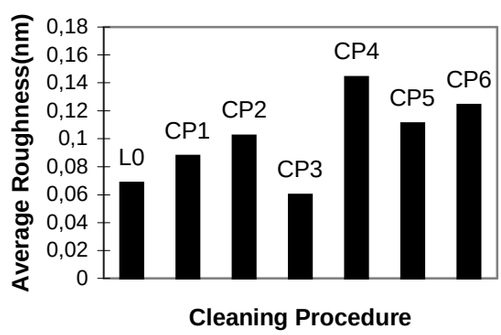

Figure 1. Average roughness as a function of the cleaning procedure (L0 is a typical as-received wafer).