# CHAPTER FIVE: CONCLUSION

## 5.1 Formation of copper dots on oxidized wafer surface

Defects such as D-defects, particles and metallic contamination can be induced on wafer during crystal growing and wafer processes. Defects that are present on the surface or near the surface are integrated into the oxide layer during thermal oxidation. They become weak spots in the oxide layer and degrade the oxide layer differently. When these weak spots are subjected to a constant field, the weakest spots in oxide layer will breakdown first. This is followed by other weak spots in the layer. Consequently, when higher stress field is applied to the oxide, more breakdown spots will be generated. As a result, higher defect density of copper dots are formed on wafer surface.

During oxide breakdown, permanent damages are done not only at the oxide layer but are extended to wafer surface. These damages on wafer surface can be enlarged by Secco etching and can be observed under low magnification of microscope. Besides, the damages also provide localized conducting paths via the oxide layer. These conducting paths allow electrons to be supplied to oxide surface and are used to discharge copper ions at its surrounding. Consequently, copper ions are deposited on these localized conducting spots on oxide surface as copper dots.

The source of copper ions for deposition is dissolved from the copper plate (anode) by electrolysis process. Building up of copper concentration in the methanol with time is strong evident proving that electrolysis process occur during copper decoration. During copper decoration, copper ions are injected into the methanol. These positively charged cations will be driven by the potential gradient between the anode and cathode and transported to the oxide surface before they can be discharged and deposited on the breakdown spots of the oxide surface as copper dots.

Copper dot presents on the oxide surface appears as a peak and is surrounded by a grey ring. The peak at the copper dot might be due to the fact that the oxide underneath the peak is the origin of a localized breakdown spot. Therefore, copper ions are deposited for a longer time on this spot. The other possible explanation is that the oxide underneath the copper peak experiences the most severe breakdown, allowing higher current density to flow through it. As a result, more charges are supplied to the breakdown spot to deposit more copper ions. On the hand, the composition of this grey ring has been analyzed using TOF-SIMS. The result shows that the grey ring consists of metallic elements such as Na, Mg, K and Ca, rather than organic or metal-organo elements.

## 5.2 Determination of applied field by *Vox/Vapp* ratio measurement

We have pointed in section 2.1.3.3 and 4.1.7, the applied field affects the defect density of copper decorated wafer (or $V_{ox}$ since the oxide thickness used in this project is constant). Therefore, it should be measured correctly and controlled tightly. The electric field can be determined through $V_{ox}/V_{app}$ ratios measurement. However, it is found that the $V_{ox}/V_{app}$ ratios are affected by the test probe exposed length. The results show that the $V_{ox}$ measurement is not trivial and is affected by the exposed (non-insulated) length of the probe. The $V_{ox}/V_{app}$ ratios are then plotted as a function of exposed probe lengths and extrapolated to the y-axis intersect (zero exposed length) to accurately determine the $V_{ox}$ value.

## 5.3 Effects of copper concentration on copper decoration process

The copper concentration in methanol during copper decoration affects the copper decoration outcome. As a result of more copper ions available for deposition, the size of copper dots increases with copper concentration in methanol. Larger copper dots (diameter > 100 μm) are preferable in counting process because the copper dots are easier to be identified under low magnification (50 X). However, increasing of copper concentration will cause the conductivity of methanol to be increased linearly. This reduces the voltage drop across the methanol. Therefore, the actual voltage to stress the oxide layer ($V_{ox}$ ) will increase with time because the copper concentration in methanol also increases with time. Higher voltage to stress the oxide layer will cause more oxide breakdown and allow more current to flow through the breakdown regions. This again increase the copper concentration in methanol and the size of copper dots.