SURFACE INSPECTION OF COPPER DEPOSITION IN IC MANUFACTURING

Used for Copper Damascene Metallization

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This note describes how Chapman Instruments non-contact surface profilers are used for rapidly characterizing copper deposited by electroplating. Analyzing the copper surface provides feedback necessary to monitor and adjust the deposition conditions. Two different electroplated copper samples are shown, which can be easily distinguished in only a few seconds.

Introduction

Copper is rapidly replacing aluminium as the metal of choice for line widths below 0.35 µm, due to its low resistivity. The driving force behind the conversion to copper is the quest for higher speed circuits, smaller line widths and reduced fabrication costs. A 3D scan of electroplated copper is shown in Figure 1.

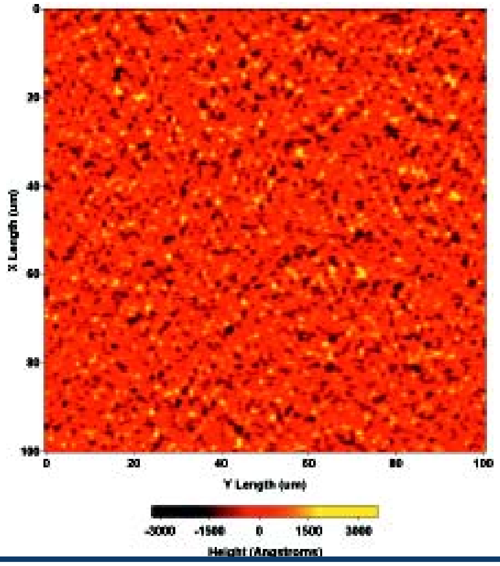


Figure 1: Three-dimensional scan of the copper layer after deposition.

Successful utilization of copper metallization is highly dependent on several enabling technologies, namely CVD (Chemical Vapor Deposition) of the barrier and seed layers, the electrodeposition of copper, followed by the planarization of the copper using Chemical Mechanical Planarization (CMP). The copper damascene metallization process can be broken down into four main steps as illustrated in the diagram in Figure 2.

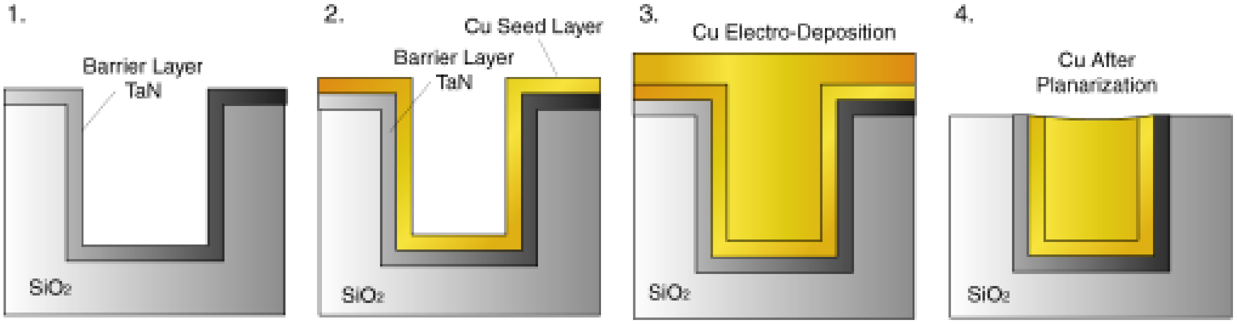
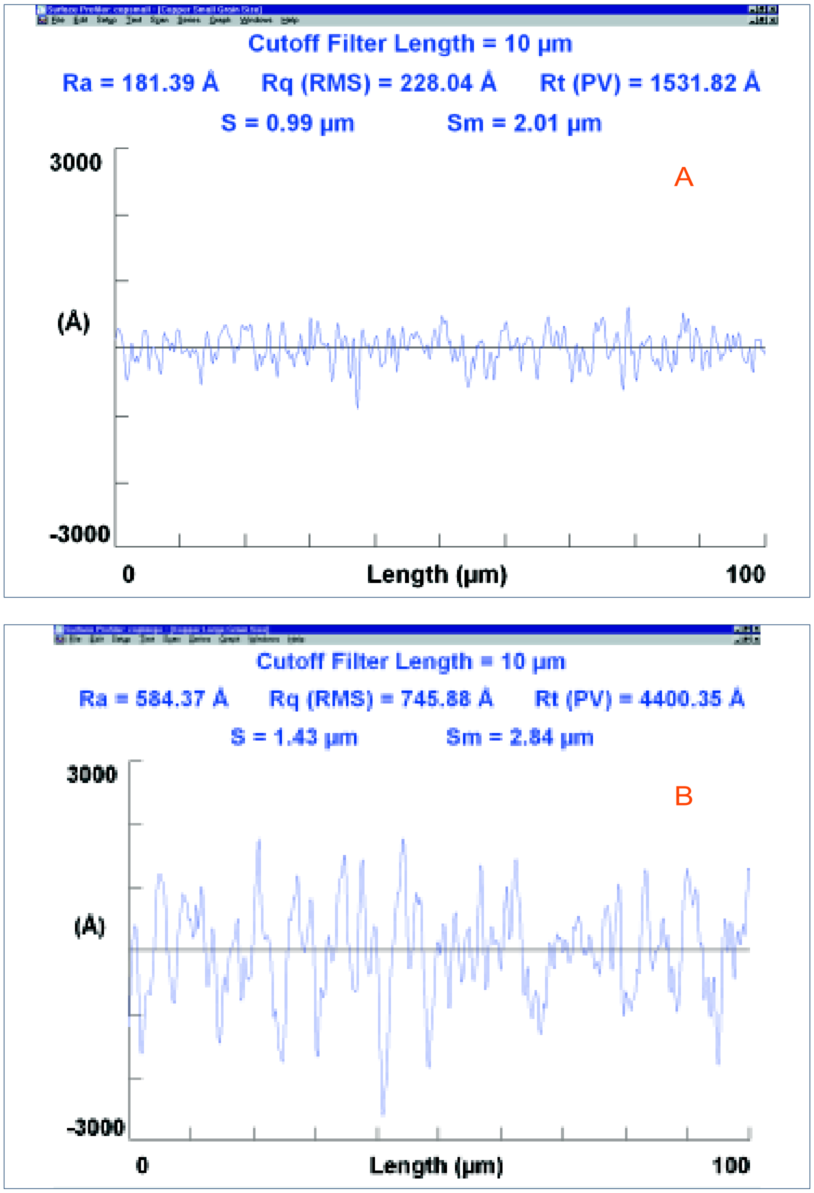


Figure 2: 1. CVD deposition of a barrier layer--typically TaN. TaN serves the dual purpose of preventing copper diffusion into the dielectric and also provides an anchor for the copper seed layer. 2. CVD deposition of the copper seed layer to act as a substrate for the copper electroplating. 3. Copper electroplating . 4. Removal of excess copper by CMP.


Cutoff Filter Length = 10 µm

Ra = 181.39 Å Rq (RMS) = 228.04 Å Rt (PV) = 1531.82 Å

S = 0.99 µm Sm = 2.01 µm

Cutoff Filter Length = 10 µm

Ra = 584.37 Å Rq (RMS) = 745.88 Å Rt (PV) = 4400.35 Å

S = 1.43 µm Sm = 2.84 µm

Figure 3: By varying the deposition conditions, and the grain size of the copper, its corresponding roughness can be dramatically altered as shown by the above line profiles. Sample A is significantly smoother and has an Ra almost three times lower than Sample B.

Experimental

One of the many factors of concern in the copper deposition process is the copper grain size. In general, the larger the grain size, the higher the resistivity, and the greater the chance of void formation. Grain size is primarily determined by the conditions of the electroplating bath and the power supply. By varying the deposition conditions, and the grain size of the copper, its corresponding roughness can be dramatically altered as shown by the line profiles in Figure 3. All samples were scanned on the MP2000 Plus optical profiler; each sample was scanned using a 20X objective lens with a Nomarski # 2 prism setting. The scan speed was 400 µm/s with a 0.2 µm sampling interval. The time for each scan was 0.25 seconds. Sample A had an Ra value of 181.39 Angstroms, whereas the rougher Sample B had a value that was more than three times larger, Ra = 584.37 Angstroms.

Conclusion

The use of optical non-contact profiling can dramatically improve process optimization, leading to an increase in yield, higher throughput, and resulting in reduced production cost.

For more information on this and other applications for our surface measurement equipment, please visit our web site, www.chapinst.com.