CHARACTERIZATION OF SELF AND THERMAL ANNEALED COPPER FILMS ELECTROPLATED BY VARIOUS CHEMISTRIES

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Electrochemical plating (ECP) emerged as the preferred deposition method for advanced damascene interconnect schemes [1]. Organic and inorganic additives are added in the plating bath to alter the deposited Cu film properties and to improve the gap filling [2].

In this study, microstructural characterization of electroplated self and thermally annealed blanket Cu films processed under various current densities, current waveforms and baths chemistries was performed. The final microstructure of the electroplated Cu film determines the resulting film properties, like resistivity, texture, and stress. The relationships between the bath chemistries, applied current densities, the kinetics of self-annealing and the final microstructure of the film is reported and explored in this study.

1 µm thick Cu films are electroplated using a commercial plating tool with 3 different plating chemistries as shown below.

Plating Bath	Composition	Supplier
Chemistry A	2 additive component	Shipley
Chemistry B	2 additive component	Enthone
Chemistry C	3 additive component	Enthone

The applied DC current density varied from 3.2 to 57.3 mA/cm^2. In addition, a multi-step DC current waveform was also used. Resistivity and stress was measured by 4-point probe and an optical curvature tool respectively. Microstructure characterization was performed using FIB (Focused Ion Beam) imaging techniques and XRD. Cu film impurities were quantified by SIMS.

FIB imaging show similar microstructure of the self-annealed (> 700 hrs after deposition) Cu film plated with the different bath chemistries. However, XRD results on these films show that the inclusion of an additional additive into the plating bath does have a randomizing effect on the (111) orientation of the plated film. The applied current density also have an effect on the texture of the plated film, with 23.9 mA/cm^2 having the highest (111) orientation. This is attributed to the growth kinetics of the plated film with the different applied current density. The resistivity and stress of the Cu film plated from Chemistry C is higher than the Cu film plated with Chemistry B. However, the self-anneal rate of both films are comparable. This suggests the additional additive results in more incorporation of impurities into the film. This is further supported by SIMS data, whereby, a film plated from Chemistry C (3 component additive plating bath) has higher level of S, Cl, C and N impurities than Chemistry B (2 component additive plating bath). FIB imaging reveals similar microstructure of all the self-annealed films supporting the SIMS data that the rise in resistivity is due to impurity incorporation rather than grain boundary scattering. Impurity level of the as-deposited and thermally annealed films is of the same order of magnitude regardless of plating bath. This suggests minimal outdiffusion of the impurities.

Results show that the kinetics of self-anneal is a strong function of applied current density, current waveform and bath chemistry. Chemistry A have a faster self-anneal rate than Chemistry B despite plating at the same current density.A slower rate of self-annealing, and stronger (111) orientation is obtained from films deposited with a DC mulit-step waveform than a single-step DC regardless of the chemistries. Slightly stronger (111) orientation is obtained from self-annealed films than thermally annealed films regardless of bath chemistries. This indicates that the thermal anneal step slightly randomize the film crystal orientation.

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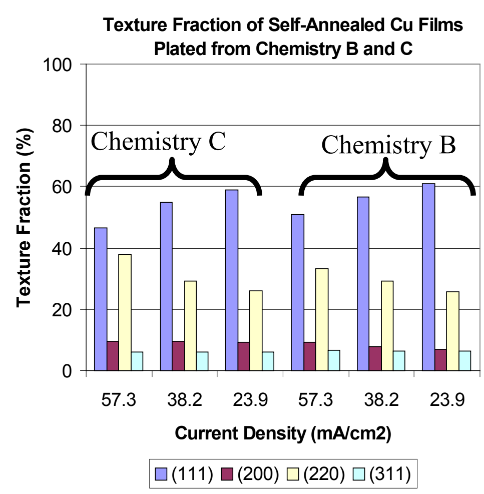

Fig 1: Texture fraction of self annealed films plated from different bath chemistries. Decrease of (111) orientation is observed on film plated with a 3 additive component plating bath

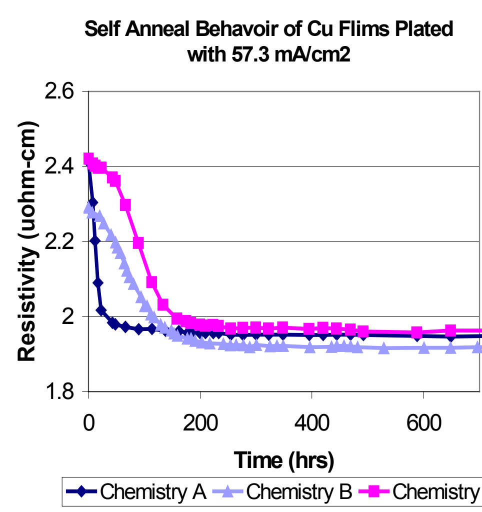

Fig 2: Self annealing behavior of films plated at the same current density. Self annealing rate is different from films plated with Chemistry A vs Chemistry B, C.