IMPACT OF THE ADDITIVES AND THE CURRENT DENSITY OF COPPER ELECTROPLATING PROCESS ON THE BACKEND-OF-LINE METALLIZATION OF ULSI

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Cu electroplating has become a critical metallization process for 0.13um & below generation as it provides high throughput, low COO and bottom up gap fill [1-2]. Nowadays, widely use plating solution consists of 3 common additives: Accelerator (A), Suppressor (S) and Leveler (L), added into $CuSO_4$ + H_2SO_4 + Cl base electrolyte (VMS). Due to its complexity, the relationship between additives, current density (CD) and physical properties like pitting defects and impurities of the films are not clearly understood. In this work, a systematic approach was used to investigate these. Additives from Enthone were used to mix various solutions: VMS, S+VMS, A+S+VMS and L+A+S+VMS. For each solution, CD ranging from 3.33mA/cm^2 to 60mA/cm^2 were used to produce 0.3um or 1um films on both 8' blanket and pattern wafers using NVLS Sabre xT platform. The Barrier/Seed scheme used is 250Å Ta + 1500Å Cu deposited by Hollow Cathode Magnetron. AIT XP, EV-300 and SIMS were used to analyze the defects and impurities in the film. In addition, the gap fill capability of the various solutions and effect of CD were studied by FIB.

We found that S is perhaps the most critical additive in the bath when obtaining a defect free Cu film. Good surface appearance is observed on VMS plated film for all the CD tested, indicating the same degree of surface wetting within a wafer when Cu seed immerses into the bath. The uniform wetting is found to degrade when S is added into VMS, for CD of 25mA/cm^2 and above. This non-uniform wetting generates numerous water-fronts, which results in thickness variation within the Cu film. This will eventually appear as a wafer spin pattern shown Figure 1a. Addition of A into S+VMS improves the wetting significantly, leaving only 1 line of water-front, as shown in Figure 1b. This water-front is believed to be the boundary between the first and last wet region, with potential of forming a line of pit defects, known as "swirl" [3]. The addition of L into A+S+VMS further improves the wetting and no swirl is detected by AIT scan. The actual mechanism of this improvement remains unclear. However, it is believed to be related to the better wettability caused by the displacement of S with A [2,4], and the leveling and grain refinement capability of L, whereby plating at thicker regions is suppressed to allow the later wetted regions to catch up as the plating process proceeds.

SIMS analysis results from 0.3um Cu films are summarized in Figure 2. They suggest that A+S+VMS plated film has the highest purity except for slightly high S incorporation at 3.33 CD. This is followed by VMS plated film with exception of high C at 3.33 CD. Significant increment in impurities is seen with the addition of L into A+S+VMS, especially at low CD. Impurities generally increase with decreasing CD in all solutions, except S+VMS, which not only shows a reverse trend, but the impurity levels also vary more widely with CD.

Figure 3 shows poor gap fill capability for VMS and S+VMS, while plating in A+S+VMS is more tolerable to poor seed as compared to L+A+S+VMS in achieving void-free gap fill. Despite less tolerable to poor seed and high impurities incorporation, L is still required to minimize killer defect to achieve better yield and improve overburden for better CMP integration.

Reference:

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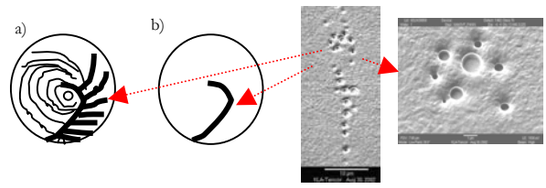

Figure 1. Schematic of the surface finish of the 0.3 & 1um EP film plated in a)S+VMS at 25mA/cm^2 & above; b)A+S+VMS at 10mA/cm^2 & above. Lines of pits are detected on these wafers.

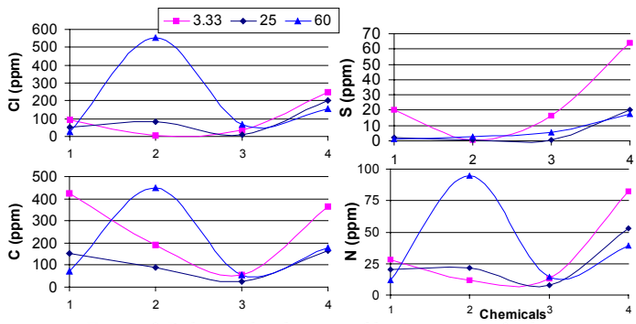

Figure 2 Relationship between film Impurities & plating chemistries (1.VMS;2.S+VMS;3.A+S+VMS;4.L+A+S+VMS & CD.

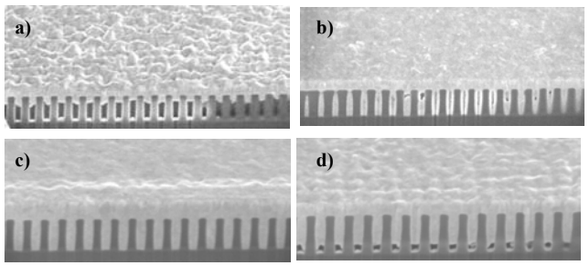

Figure 3. Gap fill capability of various chemistries a) VMS; b) S+VMS; c) A+S+VMS; d) L+A+S+VMS, to fill 0.18um, 6:1AR trench.