Modeling the bottom-up filling of through-silicon vias through suppressor adsorption/desorption mechanism

Liu Yang[1,2], Aleksandar Radisic[1], Johan Deconinck[2], Philippe M. Vereecken[1,3]

[1]IMEC, Kapeldreef 75, 3001 Leuven Belgium
[2]Vrije Universiteit Brussel, 1050 Elsene, Belgium
[3]KU Leuven, 3001 Leuven, Belgium

Void-free filling of high aspect ratio Through-silicon vias (TSVs) using Cu electroplating is achieved with the help of various organic additives, e.g. bis(3-sulfopropyl) disulfide (SPS)) as accelerator and polyethylene glycol (PEG) as suppressor. The evolution of the surface profile during plating can be quite different depending on the additive properties and plating conditions. The so-called bottom-up filling has attracted much attention recently. Such a filling mode is characterized by a fast growing flat bottom which is almost perpendicular to the slow growing lateral wall. It has been observed in both 2-component [1] and even 1-component [2] plating baths. The fast bottom growth starts at the early stage of plating without a significant area change. In this study, we focus on the role of suppressor desorption/adsorption in the bottom-up fill of TSVs. As shown in Fig. 1, both the desorption and re-adsorption of suppressor additive (PEG in this case) are dependent on the local concentrations of species such as Cl^-. The dependency of desorption potential on Cl^-, Cu^{2+} and PEG was studied quantitatively [3]. Such a desorption process may also happen inside a TSV. After the emersion of the sample into the plating bath, the via top is quickly covered by adsorbed suppressor while suppressor is depleted inside the TSV. During the diffusion-limited suppressor adsorption process, the region of high suppressor coverage propagates toward the via bottom. With a fixed input current, the current density at the via bottom increases during this process. In addition, the local concentrations of suppressor / Cl^- is lower at the via bottom compared with the via top due to consumption, thus suppressor desorption is easier at the via bottom. Under appropriate plating conditions, suppressor desorption happens at the via bottom while the sidewall is still covered by suppressor. A suppressor-free region is thus created only at the via bottom and leads to the bottom-up filling. Fig. 2 shows the simulated profile evolution of Ø5µm×40µm TSVs under various conditions. The bottom-up filling process is demonstrated for both suppressor + accelerator (Fig. 2a) and suppressor only (Fig. 2d) plating baths. The filling mode can be very different depending on the bath composition, as shown in Fig.2. These simulated results match well qualitatively the reported experimental observations [1, 2].

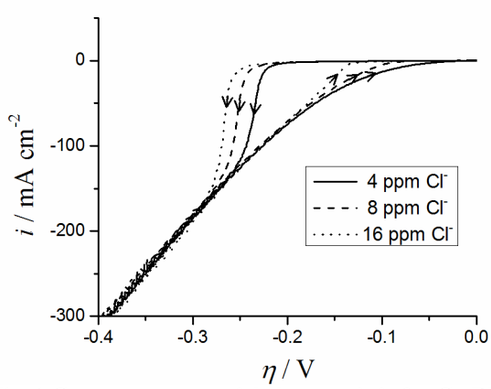

Fig. 1 Current-overpotential characteristic for Cu RDE in 1 M H_2SO_4 + 0.25 M $CuSO_4$ + 300 ppm PEG solution with various Cl^- concentrations. 1000 rpm, 20 mV s^{-1}.

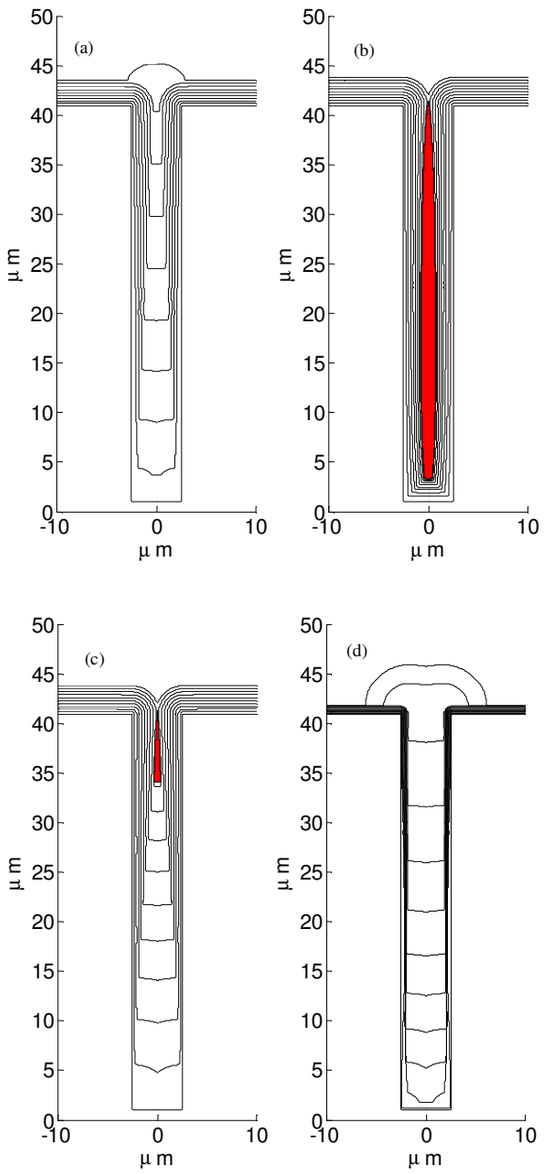

Fig. 2 Simulated profile evolution for 5 µm×40µm TSVs showing various filling modes. With suppressor + accelerator: (a) bottom-up filling; (b) sub-conformal; (c) bottom-up growth with a top void. With suppressor only: (d) bottom-up filling. The time interval between two lines is 300s for (a), (b) and (c), 100s for (d). Voids are highlighted.

References:
[1]. A. Radisic, L. Yang, C. Drijbooms, H. Bender, ECS Trans., 41(43), 53 (2012).
[2]. T.P. Moffat, D. Josell, J. Electrochem. Soc., 159, D208 (2012).
[3]. T.A. Atanasova, K. Strubbe, P.M. Vereecken, ECS Trans., 33(37), 13 (2011).