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The influence of Ga^+ ion dose on deposition rate and purity of Pt films

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We present the results of a systematic study investigating the effect of Ga^+ dose on ion-assisted deposition of platinum in a Focused Ion Beam (FIB) instrument. A series of 10 μm x 10 μm pads were deposited on a single crystal silicon substrate using the standard metalorganic platinum precursor (methylcyclopentadienyl)trimethyl platinum ($MeCpPtMe_3$) with dwell times of 0.2, 0.4 or 0.8μs, and beam currents ranging from 4pA to 12nA. At either end of the current range, no deposition was observed (for high current and long dwell times, in fact, a crater was milled out of the substrate despite the presence of the deposition gas). However, for intermediate currents ranging from 70-1000pA, appreciable deposition was observed. These films were cross-sectioned using the milling capabilities of the FIB and their composition analyzed using Auger electron spectroscopy.

Figure 1 shows a matrix of pads deposited with several beam currents and dwell times, and notes the overall effect on the deposition rate. The data demonstrate that a simple monotonic relationship does not exist between dose and film thickness, which differed by nearly 100nm, or 25% for a given dose. Even when the data are considered within a single column or row, the film deposition rate does not appear to have a simple relationship with beam current, dwell time or dose per pixel. All of this points to the existence of two or more competing and simultaneous processes. Factors which may influence the deposition include gas phase delivery of the precursor vapor; adsorption of that vapor onto the sample surface; direct physical milling of the substrate (or deposited film) and decomposition of the precursor itself.

Figure 2 shows Auger spectra from the two Pt depositions described above with similar ion doses of ~360 ions/pixel. After correction for Auger sensitivities, the film deposited using a longer dwell time and lower current was found to be ~31% Pt, while the film deposited using a shorter dwell time but higher current is ~36% Pt. Although these latter conditions also resulted in a thicker film, it cannot be assumed from these two example spectra that this correlation always holds. In fact the thickest film in the study (520 nm, deposited at 350pA with a 0.8μs dwell time) was also one of the lowest in purity (29%). In contrast, films deposited using an Atomic Layer Deposition (ALD) process employing the same precursor achieved a purity of 90% or better.[1]

Because the major non-platinum component of the FIB-deposited films is carbon, it is assumed that these inclusions are the result of incomplete decomposition of the metalorganic precursor. However, because Auger is not sensitive to extremely light elements such as hydrogen, it is unclear whether the organic ligands are being incorporated wholesale. More discriminating spectroscopy is being pursued to clarify this issue.

References

[1] Y. Zhu, K.A. Dunn, and A.E. Kaloyeros, "Properties of Ultra-thin Platinum Films Deposited by Atomic Layer Deposition," *Proceedings of the AVS 5th International Conference on Atomic Layer Deposition 2005* (in press).

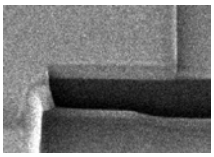
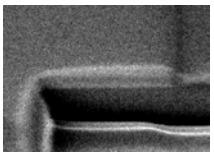
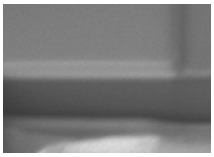
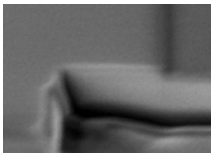
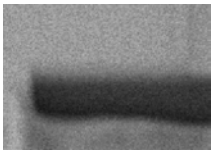
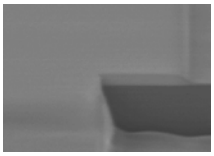
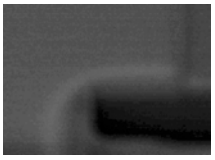
	0.2 µs	0.4µs	0.8µs
70 pA	 Dose: 80 ions/pixel Film thickness: 170 nm	 Dose: 175 Film thickness: 250	 Dose: 350 Film thickness: 350
145 pA	 Dose: 175 Film thickness: 340	 Dose: 360 Film thickness: 460	 Dose: 720 Film thickness: 300
350 pA	 Dose: 415 Film thickness: 360	 Dose: 835 Film Thickness: 290	 Dose: 1770 Film thickness: 520

Figure 3. Montage of secondary electron images showing effects of beam current and dwell time on the deposition rate of Pt in the FIB. Field of view in all cases is 12µm x 12µm (foreshortened due to 45° viewing tilt). Dose in ions per pixel and resultant film thicknesses in nanometers are also noted.

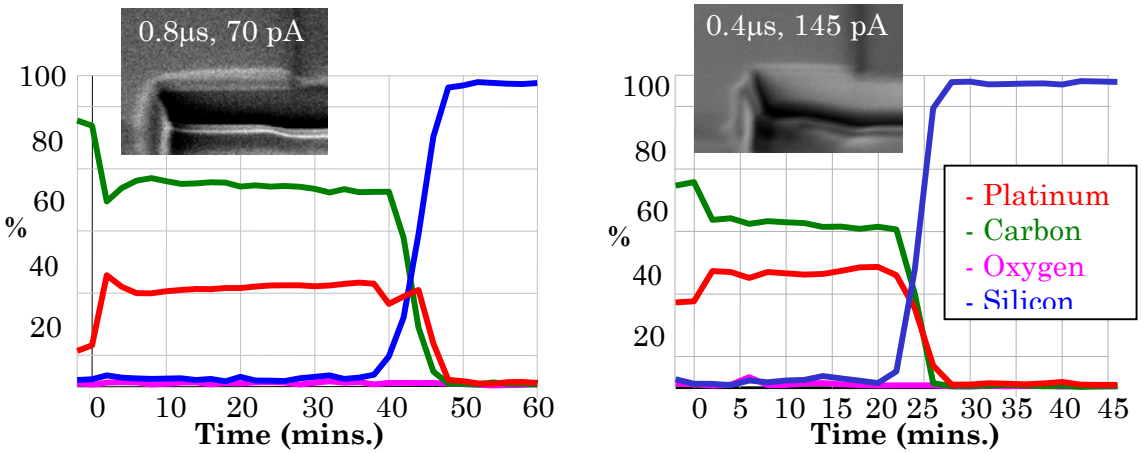


Figure 4. Auger electron spectra of two platinum films deposited with comparable dose/pixel. In this case, shorter dwell times and higher current resulted in less carbon incorporation, suggesting more efficient decomposition of the precursor. After correction for differences in sputter yields, the platinum content of the film on the left was found to be ~31%, while the film on the right had a platinum content of ~36%.

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