# IMPROVED ADHESION AND ELECTRICAL PROPERTIES OF PLASMA-ENHANCED ALD PLATINUM THROUGH CYCLE-BY-CYCLE HYDROGEN PLASMA TREATMENT

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Insufficient adhesion of platinum thin films to their underlying substrates is a cause of concern in many applications such as biomedical and MEMS devices. We report on significantly improved adhesion of plasma-enhanced ALD platinum films on multiple substrates through in-situ cycle-by-cycle hydrogen plasma treatment. Further, we demonstrate a novel method for quantifying adhesion, which involves the deposition of a highly stressed overlayer and a subsequent liftoff procedure. The effect of the hydrogen plasma treatment on film resistivity (cf. Figure 1) and uniformity (cf. Figure 2) have also been characterized, and an extreme substrate dependence has been observed, with the most extensive treatment condition resulting in an 8% decrease in resistivity compared to no treatment on $Al_2O_3$ substrates, but a 78% increase on $SiO_2$ substrates.

All films were deposited at 270°C in an Ultratech / Cambridge Nanotech Fiji ALD reactor, using trimethyl(methylcyclopentadienyl)platinum(IV) as the precursor and remote $O_2$ plasma as the oxidant, with 400 cycles resulting in approximately 20 nm thick films as confirmed by X-ray reflectivity measurements. The plasma treatment consisted of an additional 10 seconds of $H_2$ plasma and 10 seconds of $O_2$ plasma after each cycle, with purge times of 5 seconds. Various conditions were investigated, performing the treatment during all 400 cycles, only the first 200 cycles, only the first 50 cycles, or not at all.

Adhesion was evaluated using tape lift-off, and a novel method that mimics real application in MEMS fabrication processes: Two-layer photoresist is patterned with arrays of squares of various sizes on top of the platinum film, followed by e-beam evaporation of a 200 nm thick Pt layer which has a high tensile stress of 640 MPa. A lift-off procedure is then carried out on the sample, which includes submerging it in solvents and ultrasonic agitation. In case of insufficient adhesion, individual patterned squares delaminate at the interface between the ALD platinum layer and the substrate (cf. Table 1). The fraction of delaminated squares at various sizes, as observed by optical microscopy, can then be used as a quantitative indication for adhesion strength.

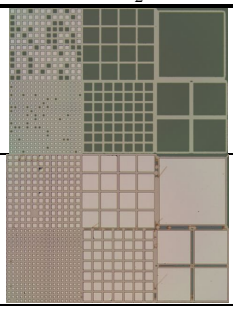
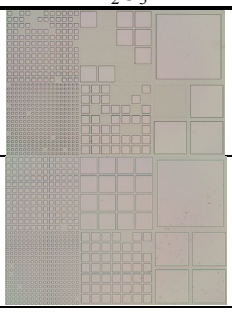
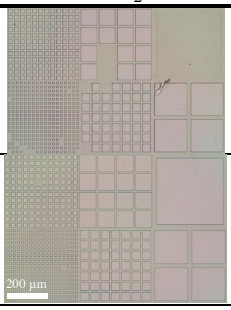
| Substrate | $SiO_2$ | $Al_2O_3$ | $TiO_2$ |
|---|---|---|---|
| No $H_2$ Plasma Treatment (0 of 400 cycles) |  |  |  |
| Full $H_2$ Plasma Treatment (400 of 400 cycles) |  |  |  |



**Table 1:** Optical microscope images showing adhesion test patterns after lift-off test for various substrates and conditions.

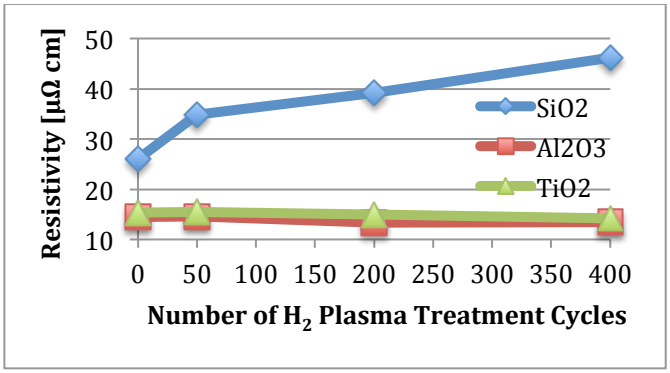



**Figure 1:** Effect of the plasma treatment condition and substrate on the resistivity of PEALD Pt films.

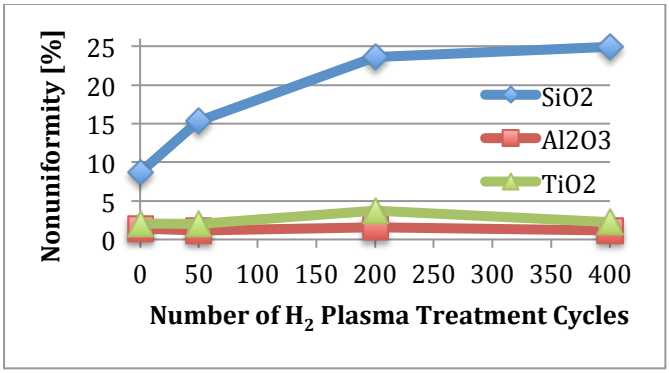



**Figure 2:** Effect of the plasma treatment condition and substrate on the nonuniformity of PEALD Pt films.