ELECTRICAL CHARACTERIZATION OF PLATINUM THIN FILMS DEPOSITED BY PLASMA-ENHANCED ALD AND MAGNETRON SPUTTERING

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Platinum is widely used in sensing applications such as thermistors, bolometers or thermal accelerometers due to its desirable thermal, electrical and chemical properties, including a high temperature coefficient of resistance (TCR), low 1/f noise, high melting point and chemical inertness. With the ability to synthesize ultra-thin pinhole-free layers with high conformality, Atomic Layer Deposition of platinum enables an even wider range of usages and fabrication processes. However, ALD of platinum also has several disadvantages compared to traditional deposition techniques, most notably low growth rate, high precursor cost and incorporation of carbon impurities into the film from unreacted precursor ligands. In this work, we compare the properties of platinum thin films from plasma-enhanced ALD (PEALD) and magnetron sputtering in an intermediate thickness regime of around 30 nm, deposited on flat thermally oxidized Si substrates.

Particular characterization and optimization effort has been put on electrical properties as those are of prime importance for sensing applications. A resistivity close to the bulk value (10.6 μΩcm) indicates a low density of impurities and other scattering sites, which correlates with better stability and higher TCR.

Sputtered films were prepared in a multipurpose sputtering system by Kurt J. Lesker Company, which is capable of both DC and RF magnetron sputtering with variable plasma power, Argon gas pressure, substrate temperature and substrate bias. Due to the large number of process parameters, a non-factorial design-of-experiments approach was used to optimize the deposition conditions for low resistivity. A summary of the first-order dependencies found is shown in Table 1. A maximum substrate temperature of 270°C was used to be comparable to the non-annealed ALD films.

PEALD of platinum was accomplished by sequential introduction of remote O_2 plasma and trimethyl(methylcyclopentadienyl)platinum(IV) precursor, performed in an Ultratech / Cambridge Nanotech Fiji ALD reactor. A variation of this base recipe with additional cycle-by-cycle H_2 and O_2 plasma treatment has shown to significantly improve film adhesion as tested by tape lift-off. Both films were deposited at 270°C and post-deposition, rapid thermal annealed at various temperatures for 5 minutes in a N_2 ambient. Figure 1 shows the film resistivities as a function of anneal temperature, with 270°C indicating no anneal. The overall findings are summarized in Figure 2. Further characterization of film morphology using AFM and TEM as well as resistivity stability is currently underway.

Parameter	Power [W]	Pressure [mTorr]	Temperature [C]	Substrate Bias [V]
DC Sputtering	↗	↗	↘	↘
RF Sputtering	↘	↘	↘	↗

Table 1: First-order effects on film resistivity of various process parameters for magnetron sputtering of Pt. Upwards arrows indicate increased resistivity with increased parameter value, downwards analogously.

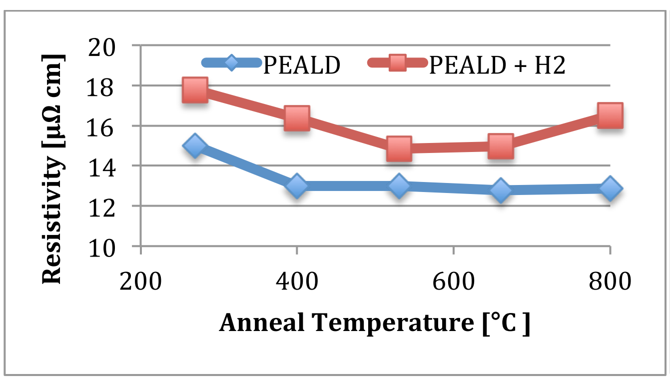

Figure 1: Effect of the anneal temperature on the resistivity of PEALD Pt films.

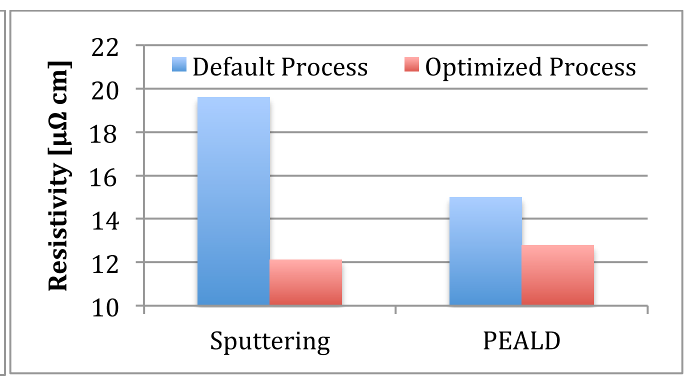

Figure 2: Comparison of the resistivity of Pt films by magnetron sputtering and PEALD.