Electrical resistivity and morphology of ultra thin Pt films grown by dc magnetron sputtering on SiO_2

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Introduction

- Ultra thin platinum films were grown by dc magnetron sputtering on thermally oxidized Si (100) substrates.
- The electrical resistance of the films was monitored during growth *in-situ*.

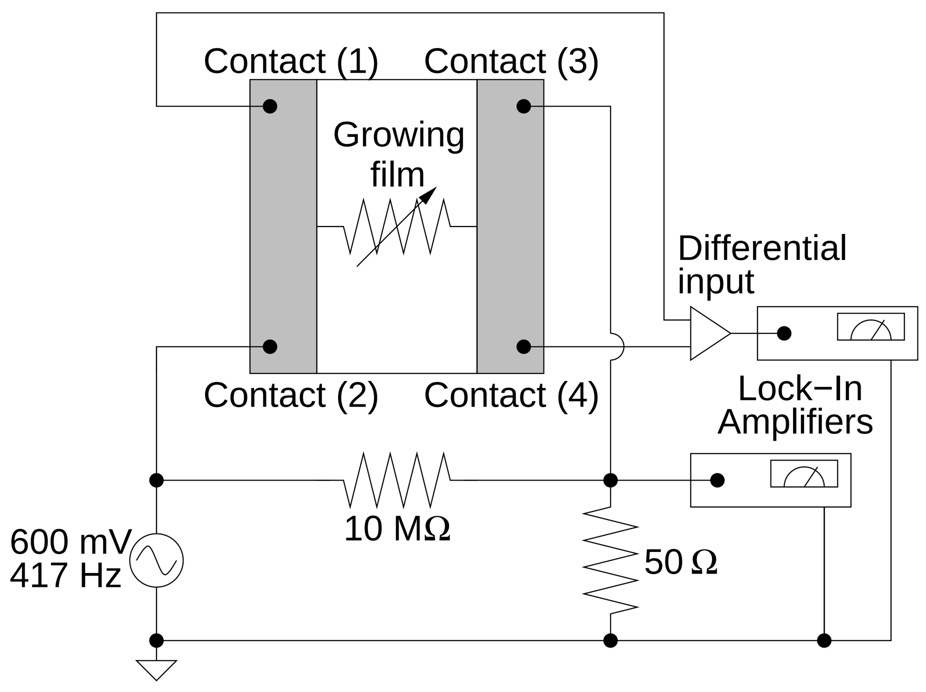

Figure 1: The dual lock–in amplifier setup used to measure the electrical resistance of the growing films *in–situ*. The setup is a standard four point probe measurement.

Experimental procedure

- The Pt thin films were grown in a custom built magnetron sputtering chamber. A turbo molecular pump was used to evacuate the system to 1×10^{-8} Torr. The sputtering gas was argon of 99.999% purity and pressure 0.4 mTorr. The Pt target was 50 mm in diameter and of 99.99% purity.
- The crystallographic grain size was determined using X-ray diffractometry and the Scherrer equation.
- The morphological grain size and surface roughness were measured *ex-situ* with a scanning tunneling microscope (STM) with an etched tungsten tip (Arnalds et al., 2003).
- The substrate holder is made from Macor ceramics to electrically isolate the four probe tips from each other and from the sample stage.
- The electrical resistance of the growing film was measured with a simplified version of the dual lock-in amplifier setup described by Barnat et al. (2003).

Results and discussion

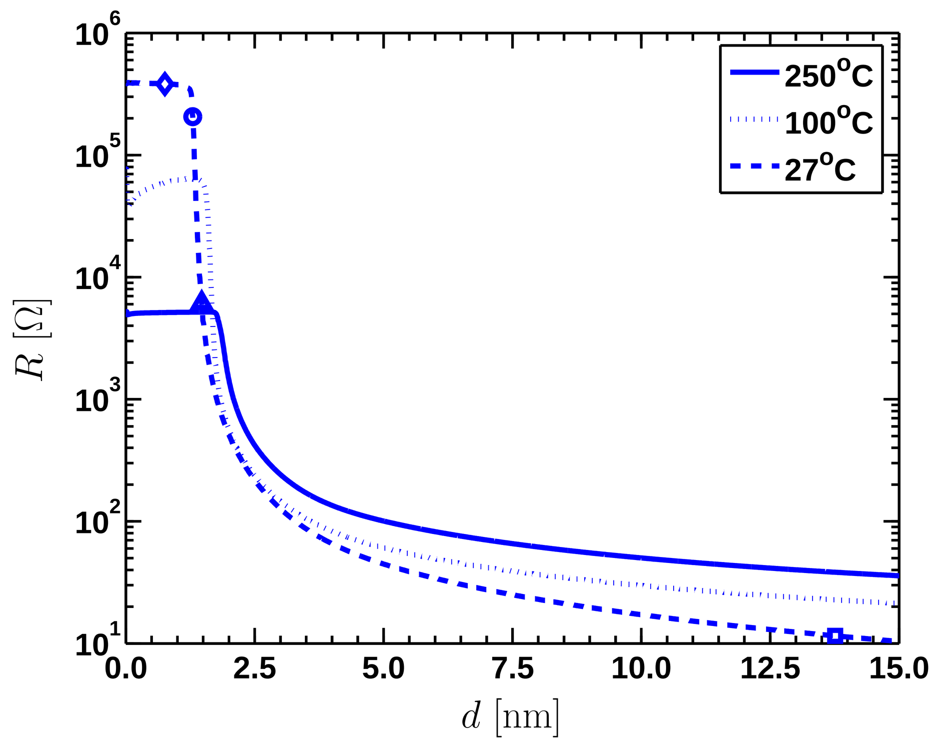

Figure 2: The resistance, R, as a function of Pt film thickness, d, measured *in–situ* during growth, for three different growth temperatures.

- The coalescence threshold is 1.3 nm, 1.6 nm, and 1.8 nm for the films grown at 27, 100 and 250°C, respectively.
- In comparison, Maaroof and Evans (1994) find the minimum coalescence thickness to be 0.83 nm, 0.67 nm, and 0.61 nm for films grown at 27, 100, and 200°C, respectively, using ion–beam sputtering.
- The minimum of the calculated value Rd^2, where R is the *in–situ* resistance and d the deposited film nominal thickness, gives the minimum thickness of a continuous film (Rycroft and Evans, 1996; Maaroof and Evans, 1994). This occurs at 3.9 nm, 3.4 nm, and 3.5 nm for the films grown at 27, 100, and 250°C, respectively.
- In comparison, Maaroof and Evans (1994) find the minimum thickness of Pt films which completely cover the substrate to be 2.30 nm for films grown at 27 – 200°C and 0.35 nm for films grown at 300°C.
- As each film becomes thicker, its resistance decreases until the room temperature resistivity reaches values close to $2.5 \times \rho_0$, $4.8 \times \rho_0$, and $8.2 \times \rho_0$ for the films grown at 27, 100, and 250°C, respectively. The bulk resistivity of Pt is $\rho_0 = 10.6\ \mu\Omega$ cm.
- Four films were grown at room temperature to different thicknesses. Immediately after growth the samples were heated from room temperature up to approximately 450°C at a rate of 1°C/min while their resistance was monitored.

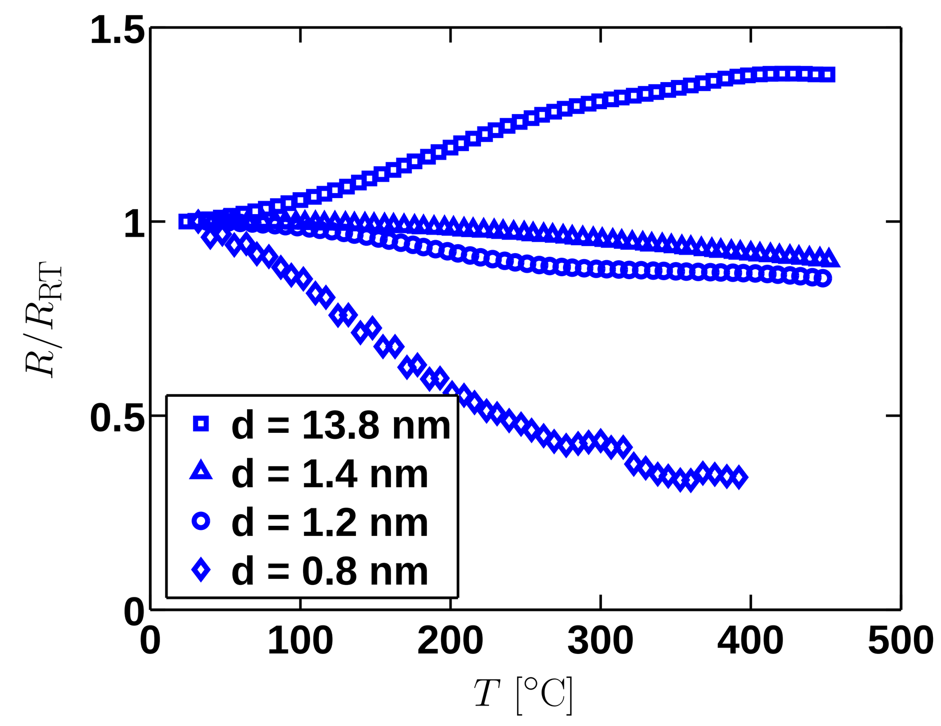

Figure 3: The normalized film resistance R/R_{RT} versus temperature for a film grown at room temperature. The symbols correspond to the symbols marking thickness and resistance shown in figure 3.

- The morphological grain size of 85 nm thick films was evaluated to be 21, 24 and 52 nm, for the films grown at 27, 100, and 250°C, respectively.
- The RMS surface roughness was estimated 1.6, 1.8, and 2.7 nm, for the films grown at 27, 100, and 250°C, respectively.
- The crystallographical grain size for 85 nm thick films was determined 30, 33 and 40 nm for the films grown at 27, 100, and 250°C, respectively.

Conclusions

- The morphological grain size and the crystallographical grain size increase with increased growth temperature, which should result in lower electrical resistivity.
- Higher growth temperature leads to increased film resistivity. This could be partially related to increased surface roughness with increased growth temperature.

Acknowledgments

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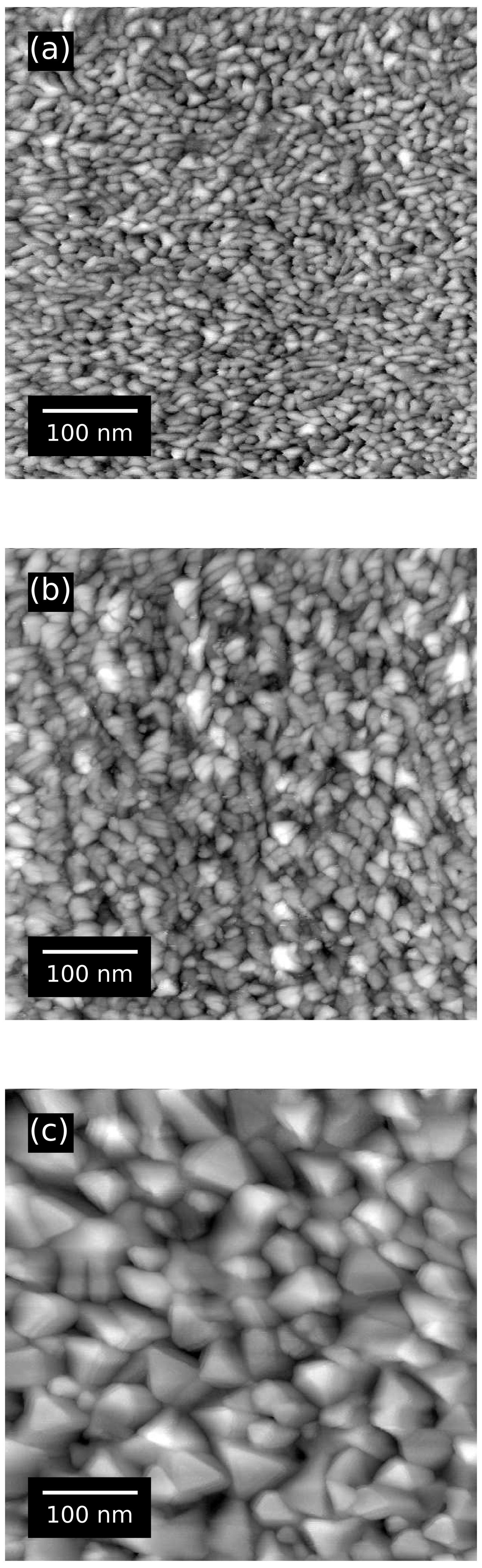

Figure 4: STM images of the surface of 85 nm thick Pt films grown on SiO_2 at (a) 27°C, (b) 100°C, and (c) 250°C, respectively.

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