Thermal stresses and cracks in a solution-processed ITO nanoparticle-thin film heater

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Indium tin oxide (ITO) nanoparticle (NP) based thin film-heaters have been extensively developed in recent years to overcome difficulties conventional ITO heaters have met, including high cost of ITO targets and slow thermal responses [1,2,3]. ITO NP-thin film heaters can be promisingly alternatives to conventional ITO heaters. Despite the promisingly capabilities, thermal degradation observed in ITO NP-thin film heaters is one of critical issues in the development for broadening their applications. Especially, repeatedly heating and cooling cycles cause substantially their thermal degradation. The NP-thin film heaters experience thermal stresses during repeatedly heating and cooling cycles and thermal stresses are responsible for cracks in the thin film heaters. Therefore, in this study, we investigate the relationship between thermal stresses and cracks for solution-processed ITO NP thin film heaters.

In this study, ITO NP thin film-heaters were fabricated by a spin-coating on quartz substrates. After the spin-coating and drying processes were repeated 10 times, the thin films were sintered at 600 °C for 30 min in vacuum. And then silver-solder paste was painted on both ends of the films to form the electrodes. Thermal stresses of repeatedly heating and cooling cycles were applied to the thin film heaters. Temperature of the thin film-heaters was measured using an infrared (IR) camera (FLIR-A645SC) with a 2% uncertainty and a sensitivity of 30 mK in air. The structural properties of the films were measured by a non-contacting optical profiler (Veeco, NT-1100).

Figure 1 shows (a) the temperature of an ITO thin film heater as a function of bias voltage and (b) the heat generation characteristics under thermal stresses at a bias voltage of 18 V. The thermal degradation caused by thermal stresses is closely correlated with the cracks, as demonstrated in 3D optical profiles in Fig. 2. The thermal stresses at high temperatures bring about severe deformation of the ITO NP thin film heater and consequently the deteriorating performance of the heater.

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[2] D. R. Cairns et al., Appl. Phys. Lett. 76, (2000).
[3] D. Sui, Y. Huang, L. Huang, J. Liang, Y. Ma, Y. Chen, Small 7, (2011).

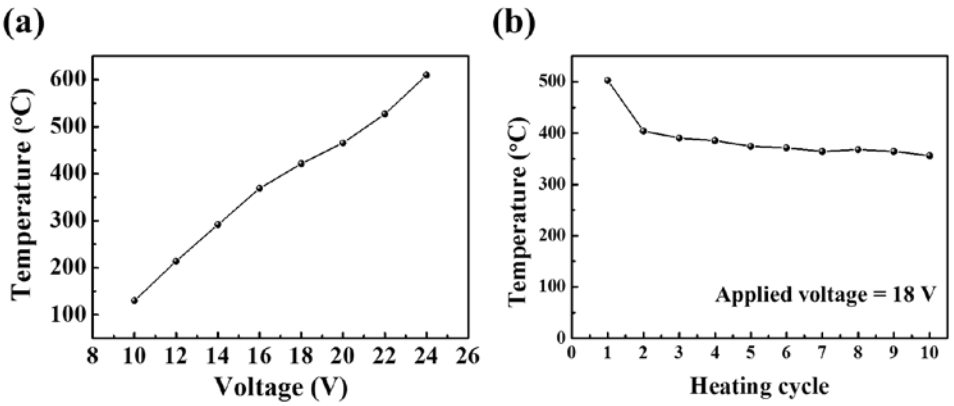

Figure 1: Heat generation characteristics of an ITO NPs thin film-heater as a function of bias voltage (a) and the heat generation characteristics under thermal stresses at an applied voltage of 18 V (b).

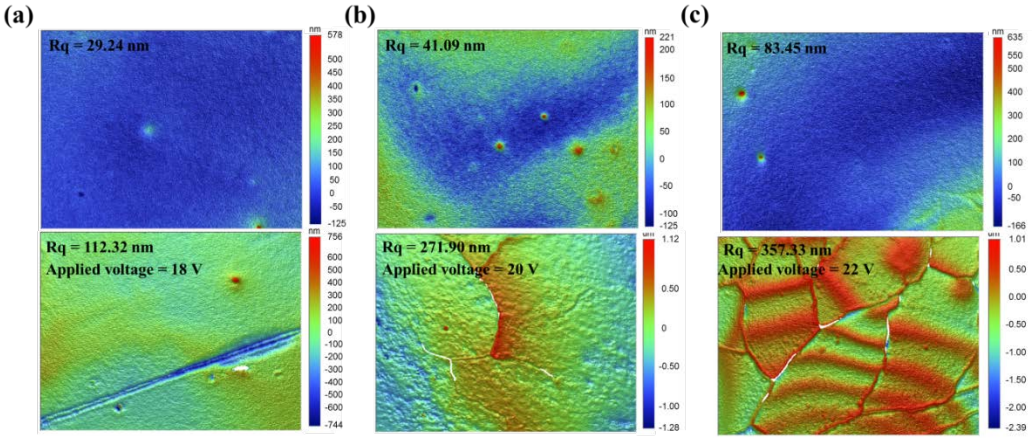

Figure 2: 3D optical profiles of ITO NP thin film heaters before and after thermal stresses at bias voltages of 18 V (a), 20 V (b), 22 V (c): Rq is a mean-surface roughness value.