Cost-effective and Solution Processed Fabrication for Metal Mesh Based Flexible Transparent Conducting Electrodes

Arshad Khan and Wen-Di Li,
Department of Mechanical Engineering, Univ. of Hong Kong, Hong Kong
liwd@hku.hk

Transparent conducting electrodes (TCEs) are key materials in optoelectronic devices such as displays, light-emitting diodes (LEDs), touchscreens, solar cells, and smart windows. For better performance of these devices, it is important to develop transparent electrodes with low sheet resistance while maintaining good optical transparency [1]. Currently the dominant materials for TCEs are thin films of transparent oxides (TCOs) demonstrating reasonably good electronic performances, but film brittleness, low infrared transmittance and low abundance limit its suitability for many industrial applications [2]. To overcome these limitations, recently there have been several new generation TCEs based on graphene, carbon nanotube, metal nanowire networks and metal mesh are introduced. These alternative TCEs demonstrate much better performance in terms of optical transparency, electrical conductivity and flexibility, however materials and fabrication methods involved in its production are expensive and time consuming which hinder its widespread commercial applications [3].

In this paper, we propose a cost-effective approach for fabricating flexible transparent metal mesh electrodes via simple solution processed steps involving lithography, electroplating and thermal imprint transfer. The schematic of the complete process is presented in Fig 1. A prototype transparent flexible copper metal grid electrode is fabricated using five simple steps including: (i) mesh pattern formation into the spincoated polymer resist (shown in Fig. 2a) on FTO glass by lithography (ii) deposition of copper by electroplating inside the trenches to form a uniform Cu mesh (iii) etching the resist to get the bare Cu mesh on glass substrate (shown in Fig. 2b) (iv) push in the bare Cu mesh into the polymer film by thermal imprinting process; and (v) separation of both the substrates to transfer Cu mesh to a flexible polymer substrate in embedded form (shown in Fig. 2c). The fabricated Cu mesh electrode exhibited an optical transmittance of 70% at 550 nm and a sheet resistance of 1.5 Ω/sq. Furthermore due to its embedded nature and unique mesh cross-sectional shape, the electrode shows no notable loss of performance under high bending stresses and demonstrate superior flexibility. Adaptation of such simple and cost-effective technique may lead to a potential alternative transparent electrode for commercial applications of solar cells, flexible displays, and other optoelectronic devices.

[1] C. F. Guo, T. Sun, Q. Liu, Z. Suo and Zhifeng Ren, Nature Communications 5, 3121 (2014)

[2] H Wu, D. Kong, Z. Ruan, P. C. Hsu, S. Wang, Z. Yu, T. J. Carney, L. Hu, S. Fan and Y Cui, Nature Nanotechnology 8, 421 (2013).

[3] K. Ellmer, Nature Photonics 6, 809 (2012).

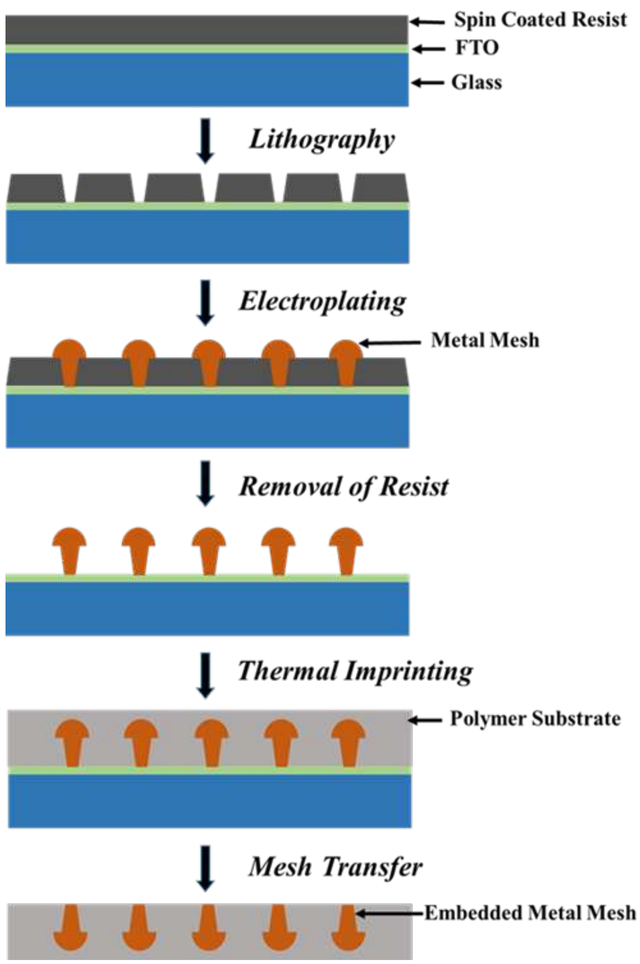

Figure 1: Schematic illustration of the Process:

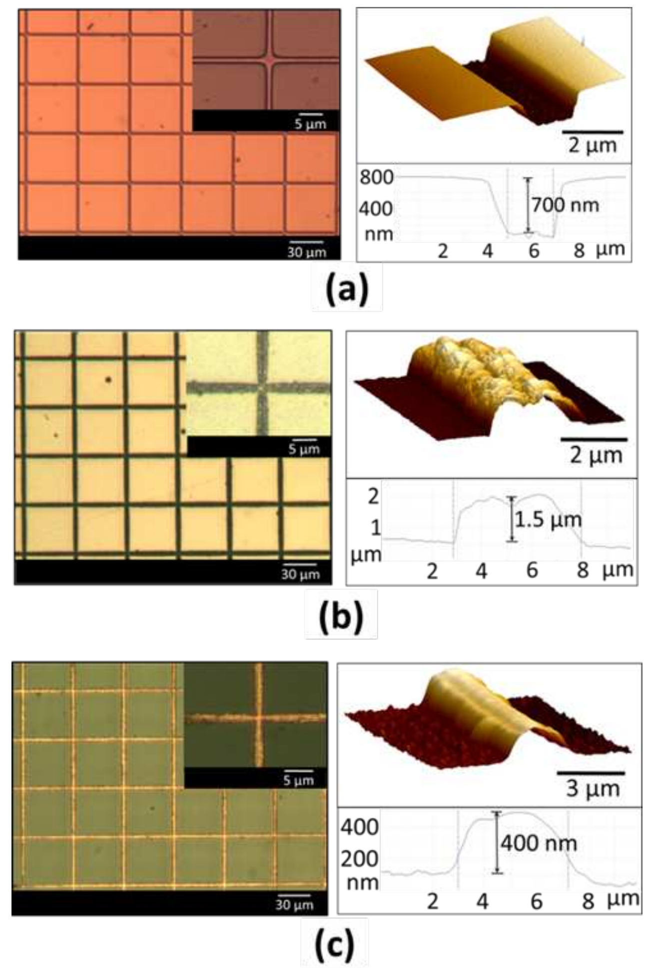

Figure 2: Optical Microscope and Atomic Force Microscope images of (a) mesh pattern in polymer resist (b) Cu mesh on FTO glass (c) Cu mesh partially embedded in the flexible cyclic olefin copolymer film.