Assembling Micron/Nanoscale Electronic Components using Optoelectronic Tweezers

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Introduction: The overarching aim of this work is to develop a new method with the potential to revolutionise the process of assembling micron/nanoscale electronic components into circuits. This will be accomplished by developing a radically new assembly strategy based on a touch-less manipulation technique known as optoelectronic tweezers. We aim to produce a step change in the size of the smallest components that can be handled from the current smallest standard component size of 400×200 μm (0402 metric) down to components a few microns across and even nanostructured components.

Background

What are optoelectronic tweezers?

Optoelectronic tweezers (OET) is a technology using a light-patterned photoconductive electrode to provide real time control over the positioning of electric fields, thus achieving particle trapping and manipulation.

The structure of an OET device

An OET device, shown in Fig.1 (a), typically consists of an upper and a lower glass slide coated with a transparent conductor (typically indium tin oxide, ITO) with the lower slide coated with an additional photoconductive layer (typically amorphous silicon (a-Si:H)).

How does an OET device work?

A light pattern is projected onto the device which creates non-uniform distribution of electric field around the area which has been illuminated. In this case, 'virtual electrodes' are generated, which can be used to corral particles via dielectrophoresis (DEP) [1], as shown in Fig.1 (b).

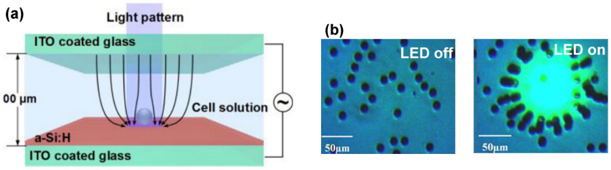

Fig.1 (a): Schematic of a typical OET device [1]; (b) particle manipulation and trapping using OET [2].

Aims

Moving Electronic Components

The main aim of this work is to assemble electronic components into circuits using OET, producing a step change in the size of the smallest components that can be assembled using the current surface mount technology. We expect to fabricate high-performance micron-sized (or even nano-sized) circuits using OET. A schematic and an microscope image of using OET to move a resistor are shown in Fig.2 (a) and (b).

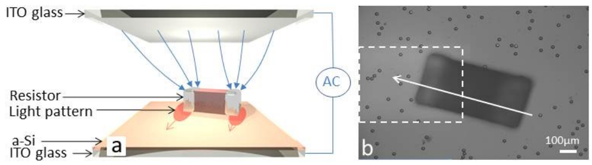

Fig.2 (a): Schematic of using OET device to move a resistor ; (b) a microscope image of using OET device to move a resistor.

Moving Nanowires to Create Conductive Path

Another aim is to use OET device to concentrate and pattern lines of conductive nanowires to form metal conductive paths acting as electrical contacts for the circuit, essentially as a form of mask-less lithography. Initial experimental results will be shown in the following part.

Experimental results

- Silver nanowires were manipulated by OET to form different conductive patterns
- Silver nanowires have a typical diameter of 100 nm and a resistivity of 10^{15}-10^{16} Ω/m
- Scanning electron microscope (SEM) images of silver nanowires with different magnification times are shown in Fig.3 (a)-(d). Note that in native solution they often appear in dense clusters, as seen in Fig.3 (d).

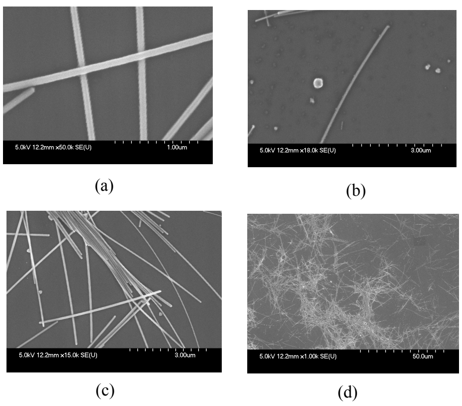

Fig.3 (a)-(d): SEM images of silver nanowires with different magnification times.

- Microscope images of a conductive suspension containing silver nanowires before and after tweezing are shown in Fig.4 (a)-(c) and Fig.5 (a)-(c).
- Silver nanowires can be moved effectively to form different patterns according to the light patterns imaged on the sample. The nanowires are contained in a solution of conductivity 10mSm-1, and are patterned using a commercial projector through the microscope, with a peak-to-peak voltage of 30V at 50kHz crossing the device.

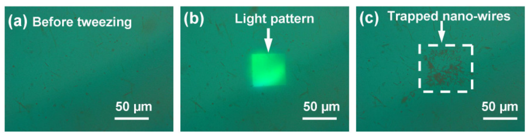

Fig.4 (a)-(c): Microscope images of silver nanowires trapped by a square light pattern.

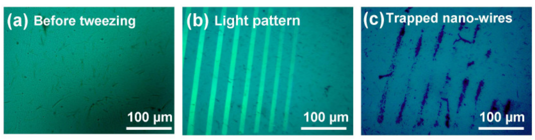

Fig.5 (a)-(c): Microscope images of silver nanowires trapped by stripped light patterns.

- Rectangular light patterns were used to manipulate silver nanowires to form a conductive metal path between two electrodes (produced by regular means of masked lithography). This method is used as a means to test the reduction in resistance caused by making the nanowire connection. Microscope images of the manipulated nanowires are shown in Fig.6 (a)-(f).

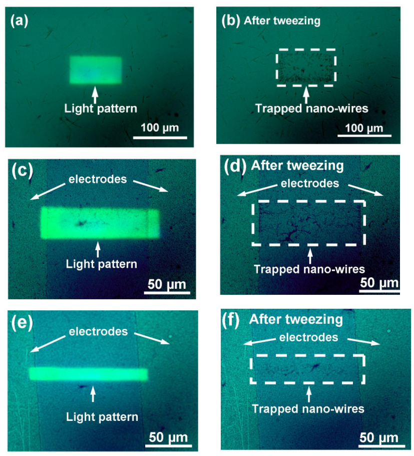

Fig.6 (a)-(f): Microscope images of silver nanowires trapped by rectangular light patterns to form metal path between electrodes.

Conclusion: We have demonstrated the use of OET to manipulate conductive silver nanowires into different patterns. A proof-of-concept demonstration was made to quantify the feasibility of using OET to manipulate silver nanowires to form a conductive metal path between two electrodes. The aim of this work is to develop a new method to assemble nanowires and micron/nanoscale electronic components into circuits.

References

[1] A. Zarowna-Dabrowska, et al., "Miniaturized optoelectronic tweezers controlled by GaN micro-pixel light emitting diode arrays," Opt. Express, vol 19, no. 3, pp. 2720-2728, 2012.

[2] A. H. Jeorrett, et al., "Optoelectronic tweezers system for single cell manipulation and fluorescence imaging of live immune cells," Opt. Express, vol 22, no. 2, pp. 1372-1380, 2014.

Acknowledgement

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