Core Shell Nanowire Surface Fastener Used for Mechanical and Electrical Room Temperature Bonding

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Abstract This paper presents a method of fabricating surface fastener for the application of mechanical and electrical room temperature bonding based on core shell nanowire array. This surface fastener consists of core shell nanowire array with the copper core and parylene shell. The copper nanowire array on the silicon substrate was prepared through template-assistant electro-deposition, which provided the electrical conductive function. The parylene shell was deposited on Cu nanowire array through CVD method, which provided surface compliance to increase contact areas, thereby realizing larger bonding strength. Through pressing core shell nanowire arrays against each other, the van der Waals forces between the interpenetrating nanowires had a contribution to the room temperature. This room temperature bonding technology may enable the exploration of a wide range applications involving assembly of components in the micro electronics.

Keywords Core shell, Nanowire, Surface fastener

1. Introduction

The continuous trend towards miniaturization and functional density enhancement makes an urgent demand to improve the bonding technology in the surface mount technology. The traditional bonding technology utilizes the solder. However, solder has relatively high electrical properties and copper-tin intermetallics have poor mechanical propertities[1]. An all-copper connection technology has been introduced, but the annealing temperature range of 350-450°C is too high for cost-efficient organic broads or substrates[2]. Moreover, the surface-activated bonding method has been reported, which can be performed at room temperature[3, 4].However, the high electrical resistance (above 1000Ω) may prohibit it application in electrical interconnection. Therefore, to create a bonding technology which not only has good mechanical and electrical property but also does not need high processing temperature is always a destination for the researchers.

With the efficient utilization of von der Waals forces, the gecko can firmly attach to and rapidly detach from varied kinds of surfaces. Many methods have been used to replicate this adhesion mode by some well-arranged micro and nanostructure arrays. Some gecko-inspired adhesive designs with nanowire arrays were cast through porous membranes available from commercial suppliers[5, 6]. Moreover, some special polymer micro and nanostructures, such as mushroom-shaped fibers[7], wedge-shaped fibers[8], bent fibers[9], spatula tips[10], led to bigger strength but also a more complicated manufacturing process. Recently, by using vertically aligned multiwalled carbon nanotube (MWCNT) with curly entangled end segment[11], the extremely high shear adhesion (~100 N/cm^2) was obtained, which was ten times higher than gecko's adhesion strength. Compared with the template method, the chemical vapor deposition method used to fabricate MWCNT is expensive and need high processing temperature.

Recently, a new kind of bonding technique based on core/shell nanowire structure has been demonstrated[12]. Moreover, electrical connector can be obtained through depositing a thin metal film on the nanowires[13]. Although this structure can achieve mechanical interconnection at room room temperature, the high temperature in the fabrication process and the relatively high electrical resistance prohibit their application in the bonding technique in micro electronics. In this paper, copper/parylene core/shell nanowire surface fastener was investigated and showed much better electrical properties. The copper nanowire array on the silicon substrate was prepared through template-assistant electro-deposition, which provided the electrical conductive function. The parylene shell was deposited on Copper nanowire array through CVD method, which provided surface compliance to increase contact areas, thereby realizing larger bonding strength. In term of pressing the two nanowire array against each other, high adhesion strength was obtained at the same time due to the von der Waals forces between the interleaved nanowires. The according electricity resistance measurement showed that the electrical resistance of core/shell nanowire array was small.

2. Experiment details.

2.1. Electrodeposition of copper nanowires

Polycarbonate (PC) membranes (ISOPORE, Millipore Inc.) containing 0.1 μm diameter pores were used as the templates. The cathode was fabricated through sputtering 50 nm Cr adhesion layer and 100 nm Au seed layer on the substrate. With the help of isolation holders, the PC template was fixed right above the substrate. Copper nanowire arrays were then synthesized by electrodepostion under a constant current of approximately 0.003A. The electro-deposition electrolyte used was a 0.4 M $CuSO_4{\cdot}5H_2O$ solution, adjusted at pH=2 with sulfuric acid. The electro-deposition was performed at room temperature and without stir. After etching in methylene chloride to remove the PC membrane, the freestanding copper nanowire array on the substrate was obtained.

2.2. Parylene coating

As shown in figure 1, parylene-N was deposited on copper nanowire arrays by using a DACS-LAB deposition system. A typical deposition condition used in this work was 160°C for the vaporization of the parylene dimmer precursor, 650°C for the pyrolysis of the dimmer into monomers, and 60mTorr for the vacuum chamber. Through controlling the amount of the loaded precursor, the according thickness of parylene shell could be obtained.

2.3. Testing of parasitic resistance and bonding strength

The samples were connected to each other under the preload of 29.4N，and then the parasitic resistance was measured by the four-point probe method (figure 3a) after the preload was completely removed. During the measurement, electrical current from 0 to 20 mA was applied by the current source to the four-point probe measuring circuits and U-I curves were generated. The shear bonding strengths were tested by measuring the maximum forces that the surface fasteners could afford. The weights of a balance ranging from 1g to 1kg were used to fulfill this testing.

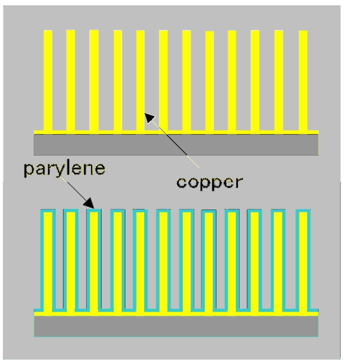

Fig. 1 Schematic of parylene coating

3. Results and discussion

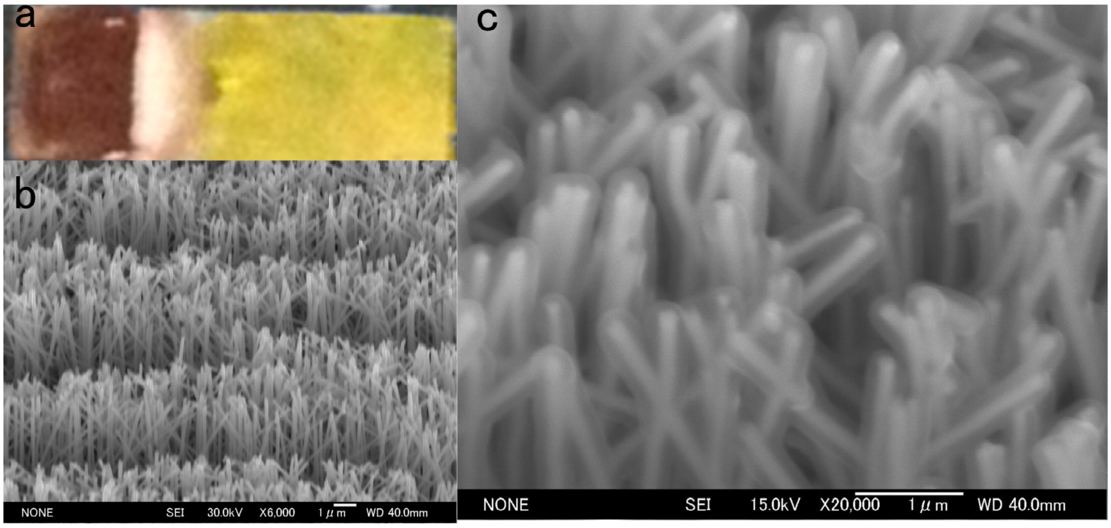

Fig. 2 (a) Photograph of the sample (b) SEM image of the fabricated nanowire array (c) SEM of the nanowire array after the parylene coating

As can be seen in figure 2a, it was easy to distinguish the fastener area from the Au film via their surfaces because the former became red in color. Scanning electron microscopy (SEM) observation (figure 2b) indicated that copper nanowire array grew on all the red area and the length of the nanowire array was uniform in most areas. From figure 2c, many relative dark shells around the bright wires could be observed. Because the parylene is non-conductive, it is darker than the copper in SEM image. The thickness of the shell was measured to be about 50nm.

The voltage-current (*U-I*) curve of interconnected fasteners is shown in figure 3b. The solid line in the figure was obtained through linear fitting of the measured values. Typical Ohmic contact performance was observed and parasitic resistance of 0.82 Ω can be extracted from the slopes of the fitted line. This result is possible to be used as the electrical bonding in surface mount. Figure 4 shows photograph of surface fasteners sustaining a weight of 500g in the shear direction. This bonding strength corresponded to the adhesion strength of 50 KPa. The purpose of our research is to develop a new mechanical and electrical room temperature bonding in surface mount. Regarding to the room temperature bonding or solder in surface mount, there are some design guidelines about the ratio between the component's weight and the bonding area. According to the standard value for second side reflow mounting (R=30g/in^2)[14]. If we consider this weight-area ratio to be R=50g/cm^2, which is more than ten times than the standard value. The bonding strength (S=50kPa) can withstand an acceleration of a=S/R=100N/kg>10*g (g=9.8N/kg is the acceleration of gravity). This result means that this room temperature bonding technique can be used in most equipment.

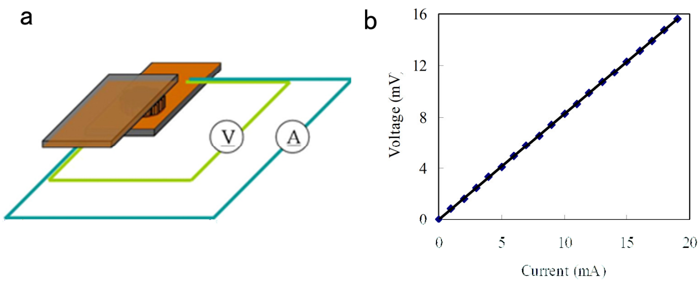

Fig. 3 (a) Schematic of four-point probe measurement (b) Measured *U-I* curves of the bonding

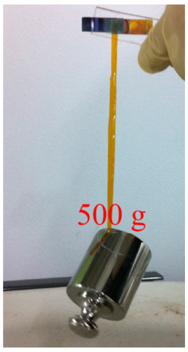

Fig. 4 A photo showing a weight balance of 100g hanging on the interconnected NSFs

4. Conclusions

In conclusion, a new kind of surface fastener composed of copper/parylene core/shell nanowire arrays has been proposed through which electrical and mechanical bonding can be realized at room temperature. Electrical measurement indicated that the electrical resistance of the interconnected nanowire array on the fastener is around 0.82 Ω under the preload of 29.4 N. The bonding strength of approximately 50 kPa was obtained. Therefore, this kind of core/shell nanowire surface fastener is hopeful to be used as electrical and mechanical room temperature bonding in the surface mount.

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