Laser Assisted Welding of Layered Metallic Nanostructure

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ABSTRACT

We present laser assisted welding of the layered metallic nanostructure, including two gold NWs and insulating layers, to reveal a prominent approach to interconnect the nanostructures in different layers. Since these nanostructures are building blocks for plasmonic integrated circuits, this work provides a promising and simple technology for the development of nanowire-related plasmonic or electric interconnect.

Keywords: *nanowelding; metal nanowires; multilayer structure*

1. INTRODUCTION

Nanowelding of nanowires (NWs) opens up a new emerging set of applications in transparent conductors [1], thin-film solar cells [2] and cancer therapy [3]. In particular, NW-based electronic and photonic circuits may significantly enhance the performance through welding of NWs. However, previous works are mostly focused on large-scale NW meshes and large area welding, the nanowelding for functional electronic and photonic devices is much less studied but highly demanded.

In our previous work [4, 5], optically-controlled local plasmonic nanowelding and nanosoldering technique is proposed and demonstrated. Our technique shows great potentials for high-performance electronic and photonic devices based on NWs, such as nanoelectronic circuits and plasmonic nanodevices. In this paper, the multilayer structure consisting of gold NWs and insulating layers is welded. It improves the conductivity of the multilayer structure while its original structural integrity is retained. This method reveals a prominent approach to interconnect the circuits in different layers.

2. MATERIALS PREPARATION AND DEVICES SETUP

Gold NWs utilized in the experiment are synthesized by wet-chemical approach [7]. Initially 50 ml of ethanol 0.72 mmol/L is added to the conical flask with water bath of 20 mins under 95 °C. Then 710 μl of 0.1 mol/L ethanol aniline is added with vigorous stirring under constant temperature of 95 °C. As the color of solution changes from brown to dark violet, we obtain the required solution and then wash and filt the solution with ethanol by paper-filters. Finally, we get the mixture of gold nanoplates and gold NWs. The NWs are about 300 nm in diameter. Then 1.5 ul of solution is dropped onto a cleaned glass wafer for further experiment.

In the welding, the 532 nm laser beam (continuous laser) with a maximum power of 1.5 W is focused by an objective (100×, NA = 0.5) on the NWs. A CMOS camera is used to record the process of welding. The spot size of the focused laser beam is about 400 nm in diameter.

3. EXPERIMENTS AND DISCUSSIONS

The schematic in figure 1 demonstrates the welding for the multilayer nanostructure consisting of gold NWs and insulating layers. Firstly, gold electrodes, depicted as golden quadrangles in Fig. 1, are fabricated by the FIB. Secondly, a gold NW, shown as a thin golden cylinder in Fig. 1, is transferred on the gold electrode by a nano-fiber-taper. Thirdly, ten layers of polymers (PSS and PAH) are coated layer by layer on the gold NW and gold electrodes [6], which is presented as a blue quadrangle in Fig. 1. Fourthly, the second gold NW is transferred on the polymer layers and above the first gold NW. The second gold NW is welded onto the gold electrode underneath by a focused laser to ensure a good conductivity between them. The resistance of the multilayer structure is measured by the source-meter (Keithley 2602). The resistance value is considered as infinite since the value is larger than the maximum range (10 GΩ) of the source-meter. This predicts that the in-between polymer layers insulate the two gold NWs successfully. Fifthly, a focused laser is irradiated on the cross of the two gold NWs to weld them. Finally, the resistance of the multilayer structure is measured again. The resistance value is several or dozens of ohms, which presents that the two gold NWs are welded together across the insulating layers.

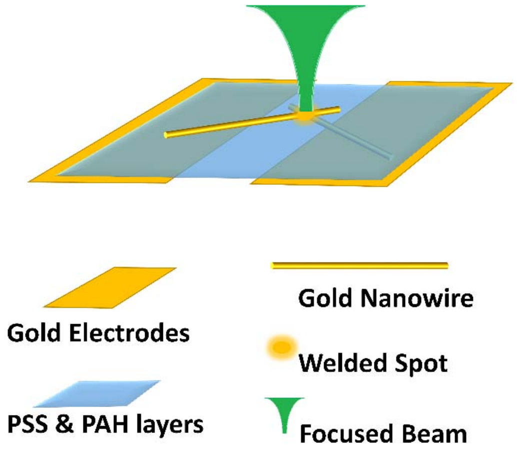
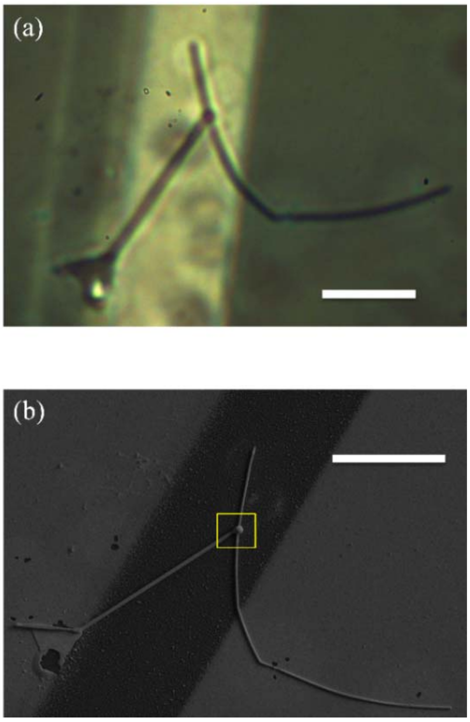


Fig. 1 Schematic of welding for the multilayer nanostructure consisting of two gold NWs and insulating layers. The yellow and blue quadrangles represent the gold electrode and PSS & PAH layers, respectively. Thin golden cylinders represent the gold NWs. A focused laser beam is shined on the cross of the gold NWs.

A typical example is shown in the figure 2. An optical microscope image and an SEM image of a welded hetero- structures is shown in Fig. 2(a) and 2(b), respectively. The zoom-in image of the welded node in Fig. 2(b) is presented in Fig. 2(c). The diameter of the top gold NW and the bottom one is 325 nm and 210 nm, respectively. The in-between insulating layers consists of five layers of PSS and five layers of PAH [6], and their total thickness is about 10 nm. Before welding, the resistance of the multilayer structure is infinite. After welding, the resistance drops to 19 Ω, and confirms that the two gold NWs are welded together across the insulating layers. This method reveals a prominent approach to interconnect the circuits in different layers.



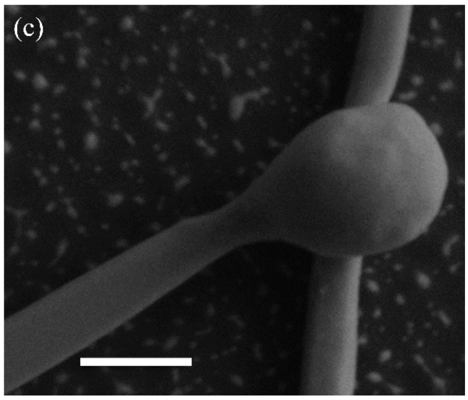


Fig. 2 An optical microscope image (a) and an SEM image (b) of welded hetero- structures is shown. Scale bar in (a) and (b) is 10 μm. The zoom-in image of the welded node in Fig. 2(b) is presented in Fig. 2(c). Scale bar in (c) is 1 μm.

4. CONCLUSIONS

In summary, we demonstrate plasmonic nanowelding of the multilayer structure, including two gold NWs and insulating layers, to reveal a prominent approach to interconnect the nanostructures in different layers. Since these nanostructures are building blocks for plasmonic integrated circuits, this study provides promising and simple technology for the development of NW-related plasmonic or electric interconnect.

5. ACKNOWLEDGMENTS

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