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Electric field-assisted assembly and alignment of gold nanorods

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For the metal nanoparticles, the alignment and assembling are simply completed by several approaches.[1,2] However, to control over metal nanorods spatial position, various envisaged applications of nanorods demand control over their collective orientation in suspension and also after deposition at the substrate. Among various approaches[3, 4, 5] of one-dimension nanomaterials manipulation, dielectrophoretic force has become increasingly popular due to the ability to fast depositing anisotropic nanorods precisely on a substrate, allowing integration with conventional top-down semiconductor processing.[6]

In this experiment, we use dielectrophoresis to make a spaced alignment of gold nanorods to avoid too close packed which will increase the reflection of substrate and result in negative effect on optical properties. In addition to spaced alignment of gold nanorods, dielectrophoresis force possesses advantages of rapid alignment as well. Therefore, by utilizing high aspect ratio gold nanorod[7] to fabricate plasmonic structure via dielectrophoresis force will considered as a quite convenient, fast, and effective method to increase the efficiency of optoelectronics. On the preliminary experiment stage, to make AuNRs aligned, a sinusoidal ac voltage was applied to gold electrodes with various voltage and gap width to estimate the optimal results on various kinds of electrodes and three different dimension AuNRs. We began at short AuNRs (200 nm in diameter) assembled into the small gap width of 0.4 µm. As the result, AuNRs were aligned well parallel to electric field under voltages of 10 Vpp, 20Vpp, 40 Vpp. As shown in Figure 1, alignment of AuNRs demonstrated a much denser arrangement with the increase of voltages. We conclude that the high applied voltage resulted in more AuNRs trapped in the electrode gaps.[8]

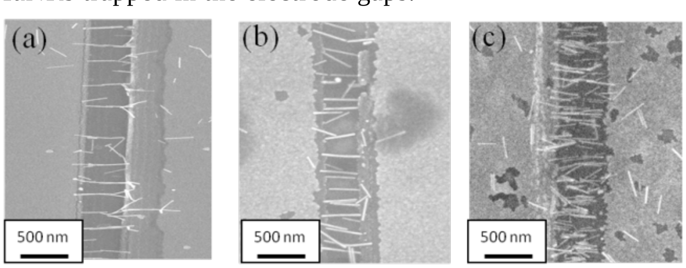

Figure 1. SEM images of assembled AuNRs with 200 nm in length in a 400-nm-width gap under various applied voltages of (a) 10 Vpp (b) 20 Vpp (c) 40 Vpp.

From Figure 1, the effect of voltage on alignment was revealed. As can be seen in these images, AuNRs were deposited predominantly within the space between two electrodes near the electrode edges. For parallel plane electrodes, the electric field as well as the field gradient was large near the electrodes. Apart from bridging between the gaps, AuNRs were attracted more inside the gap. In addition to the dense attraction of AuNRs, the improvement of AuNRs alignment also observed when the applied voltages increased.[9] The increase of applied voltages led to large magnitude and gradient of electric field. Large effective gradient of electric field contributed to large dielectrophoresis force acting on AuNRs. The increase of electric field also was contributed to large torque motion.[10] Therefore, accumulated AuNRs tended to aligned in uniform orientation parallel with the direction of electric field. We continued to demonstrate the influence of AuNRs dimension on dielectrophoresis force. After the evaporation of AuNR droplet on electrode gap of 5 µm width, the accumulation of nanorods on the edges was also observed but without bridging between the pads. To bridge the wider electrode gap, shorter AuNRs should be replaced with longer one. AuNRs would undergo the large force under the same exerted voltage that on the smaller dimension. In addition to bridge the electrode gap, longer AuNRs aligned more parallel with the electric field as well. From Figure 2, the effect of AuNRs dimension was investigated. AuNRs with large volumes also benefit the alignment result. The dielectrophoresis force increased and alignment degree improved with volume of AuNRs enlargement.

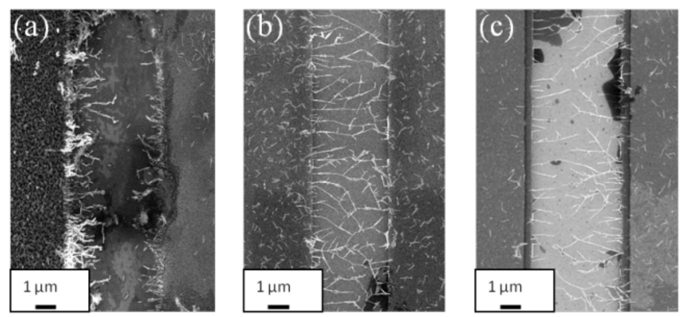

Figure 2. SEM images of assembled AuNRs with the length of (a) 200 nm (b) 400 nm (c) 900 nm on the gap width of 5 µm under 10 Vpp applied voltage.

We could conclude that while the AuNRs aligned well on the comparable shorter gap width, increase of voltage brought about denser AuNRs attracted inside the gap. In the large gap width, AuNRs went through the trend of more parallel alignment and longer chaining with the increase of applied voltages. In the future, with the help of the simulation, we would realize more about the mechanism of plasmonic solar cell with AuNR arrays and design more appropriate device to achieve greater enhancement.

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