

Electroless Gold Plating Processes for the Fabrication of Nanogap Electrodes

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Nanogap electrodes are a platform for nanodevices such as single-electron transistors (SETs) and molecular devices. They enable harnessing of the electrical characteristics of many nanostructures such as nanoparticles and functional molecules by interconnecting these nanostructures with two terminals. We have reported the simultaneous fabrication of multiple nanogap electrodes for integration of individual nanostructures into electronic circuits by a combination of electron beam lithography (EBL) (Fig.1a) and different electroless gold plating (EGP) techniques based on gold surface catalytic baths.[1] Electrodes with an initial separation of 20–25 nm were immersed into the plating solution and a gold layer grew over the electrode surface during EGP, narrowing the separation between them; growth stopped around 3 nm due to self-termination mechanisms, different for each of the plating techniques. In the iodine EGP (Fig.1b), $[\text{AuI}_2]^-$ are the plating ions and their mass transport and availability decreases as the nanogap narrows down. In the molecular ruler electroless plating (MoREP), which is based on a solution consisting primarily of alkyltrimethylammonium bromide and HAuCl_4 , the gap separation can be controlled by the chain length of the surfactant molecules in the range of 2 to 4 nm. The growth of the gold plating layer in the nanogap region stops due to the surfactant molecule interdigitation (Fig.1c) [2] or cross-linking (Fig.1d) [3] in the nanogap region. For its optimization, different surfactant molecules and plating conditions were studied. While the iodine EGP main advantage relies on its high yield (>90%) of functional nanogaps (1–5 nm in separation), MoREP's potential is the separation controllability due to the ruling molecules and have shown standard deviation of nanogaps produced in parallel as small as 0.6 nm. Conditions like temperature, concentration, immersion time, cleaning procedure, etc. played a very important role for the ideal plating results. Combination of both techniques for obtaining high yield and precise control of the nanogap separation will also be discussed. The small gap separation allowed us to interconnect gold nanoparticles in order to chemically assemble single-electron transistors simultaneously by the anchor molecule of alkanedithiol.

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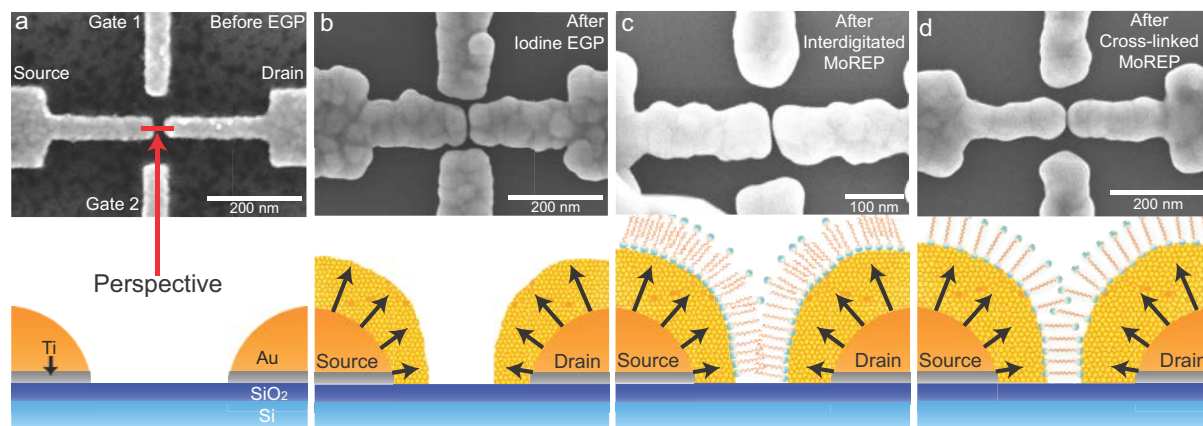


Figure 1. Scanning electron images and schematic diagram with lateral perspective of the nanogap area of the electrodes (a) before EGP, (b) after iodine EGP, (c) after interdigitated MoREP, and (d) after cross-linked MoREP.