17p-F11-10

Self-terminated Nanogap Electrodes by Electroless Gold Plating

°Victor M. Serdio[1,2], Shuhei Takeshita[1,2], Yasuo Azuma[1,2], Toshiharu Teranishi[2,3], Yutaka Majima[1,2]

Tokyo Tech [1], CREST-JST [2], Kyoto Univ. [3]

E-mail: victor@nanoele.msl.titech.ac.jp

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 (ELGP) 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 ELGP, 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 ELGP (Fig.1b), $[AuI_2]^-$ 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 interlinking (Fig.1d) [3] in the nanogap region. For its optimization, different surfactant molecules and plating conditions were studied. While the iodine ELGP 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. While the iodine ELGP 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. This allowed us to interconnect gold nanoparticles to chemically assemble single-electron transistors simultaneously by the anchor molecule of alkanedithiol.

This study was partially supported by a Grant-in-Aid for Scientific Research on Innovative Areas (No.20108011, **π**-Space) from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan; MEXT Elements Strategy Initiative to Form Core Research Center; by the Collaborative Research Project of Materials and Structures Laboratory, Tokyo Institute of Technology, the Collaborative Research Program of Institute for Chemical Research, Kyoto University (#2012-63), and the BK21 plus program, Sunchon National University through the Ministry of Education, Science and Technology of Korea (R31-10022).

[1] Victor M. Serdio V., Yutaka Majima, et al., *Nanoscale*, **4**, 7161, (2012).
[2] Yutaka Majima, et al., 72nd Fall Meeting of JSAP, la-ZQ-1, (2011).
[3] Shuhei Takeshita, et al., 59th Spring Meeting of JSAP, 17p-GP8-12, (2012).

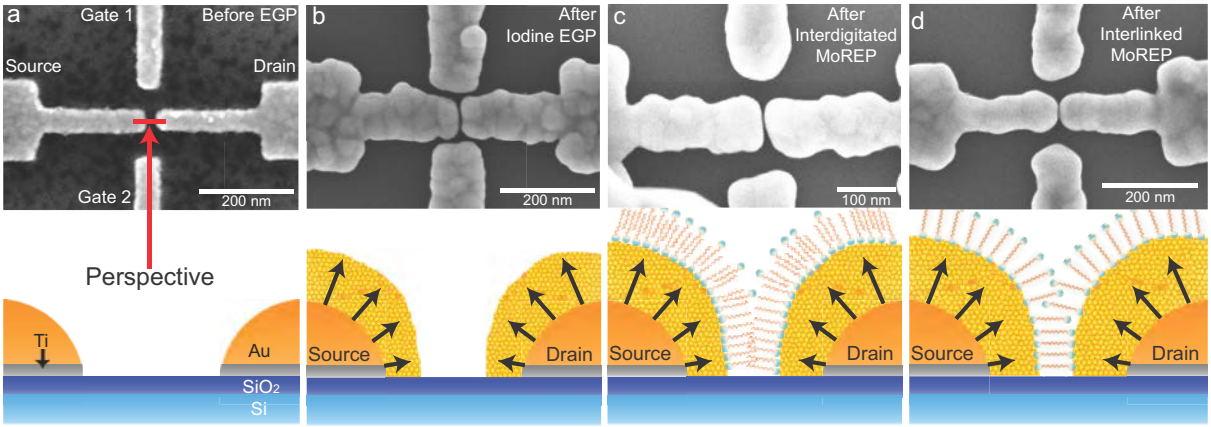

Figure 1. Scanning electron images and schematic diagram with lateral perspective of the nanogap area of the electrodes (a) before EGP, (b) after iodine EGP, (c) after interdigitated MoREP, and (d) after interlinked MoREP.