Patterning of sub-10-nm metal structures for plasmonic characterization

Joel K.W. Yang[1], Ai Leen Koh[2], David W. McComb[2], Stefan A. Maier[3], and H. Y. Low[1]
[1]*Institute of Materials Research and Engineering, Singapore 117602*
[2]*Department of Materials,*
[3]*Department of Physics,*
Imperial College London, London SW7 2AZ, United Kingdom

Plasmonics is an emerging technology with many potential applications, ranging from ultra-fast computers to bio-medical diagnostics. The ability to lithographically define metal structures with increasing control and resolution has played a significant role in the rapid growth of this field. However, lithography methods for fabricating metal structures are lacking at the sub-10-nm length scale, although high-resolution structures have been demonstrated in resist using electron-beam lithography (EBL).[1] At this length scale, chemically-synthesized metal particles randomly dispersed on substrates are commonly used for plasmonic studies.[2] But this approach is limited by difficulties in controlling the position and geometry of the metal structures.

In this work, we present top-down lithography methods to create nanostructured metal structures at sub-10-nm length scales. Using a top-down approach, the position and relative spacing of these metal structures can be better controlled than in the chemically synthesized approach. Furthermore, top-down approaches have the ability to fabricate structures of different and complex geometries (such as rings and rods) on the same substrate.

Figure 1 shows scanning electron micrographs (SEMs) of the type of structures fabricated using EBL and metallization steps. In Fig. 1a, we show a 10-nm-thick film of Ti with patterned 10-nm-diameter holes. This structure was obtained by EBL patterning of single-pixel dots in PMMA forming a repeating array of single, double, triple and quadruple hole pattern, followed by a steep-angle deposition of Ti. Such a system, consisting of a metal film patterned with holes, can be used for studies of plasmon-assisted transmission of light and as plasmonic nano-antennas for confining circularly-polarized light.

In Fig. 1b we show 8-nm-diameter gold dots fabricated on a free-standing 30-nm-thick silicon nitride membrane. These structures were fabricated by EBL patterning of PMMA followed by gold deposition via thermal evaporation and liftoff. Similar to the pattern in Fig. 1a, the dots were patterned to form a repeating array of a single particle (not shown), a dimer, a trimer and a tetramer. The fabrication on silicon nitride membranes allows for characterization of the plasmon resonances in these metal particles in an electron energy-loss spectroscopy (EELS) setup.

Alternate strategies for the fabrication of metal nanostructures combining EBL and nanoimprint lithography (NIL) will also be discussed.

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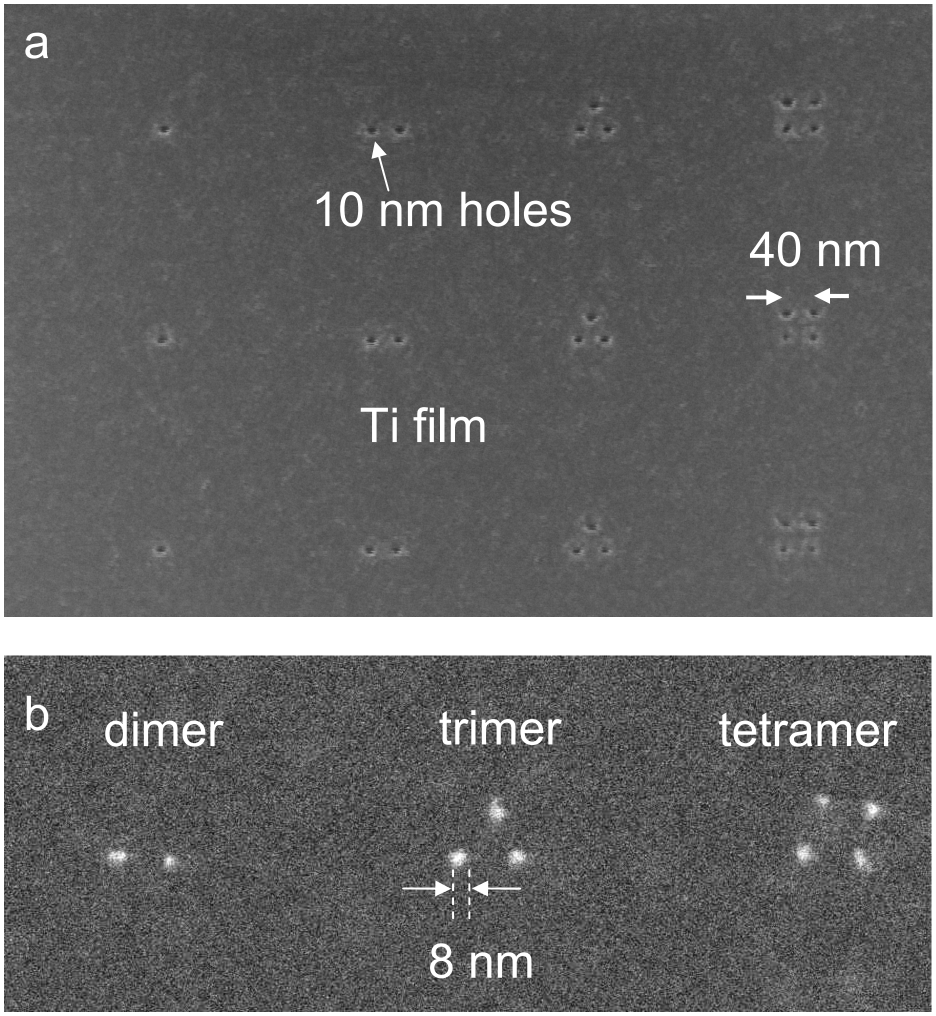

Figure 1. (a) Scanning electron micrograph (SEM) of 10-nm-thick Ti film with patterned 10-nm-diameter holes. (b) SEM of 8-nm-diameter gold dots on a 30-nm thick silicon nitride membrane for characterization in an electron energy-loss spectroscopy (EELS) setup.