Fabrication of metal nano-antennas with sub-10nm gap by using electron-beam induced deposition etch masks

I.G.C. Weppelman, P.C. Post, C.T.H. Heerkens, C.W. Hagen, J.P. Hoogenboom
Faculty of Applied Sciences, Delft University of Technology, Lorentzweg 1, 2628 CJ, Delft, The Netherlands
i.g.c.weppelman@tudelft.nl

Nanostructures with a small, sub-10 nm, gap spacing are important, e.g., for application as optical antennas. Optical antennas convert freely propagating light to localized energy, and vice versa. The strong localization and enhancement of electric fields can potentially be used for enhancing the efficiency of photo detection, light emission, and sensing[1]. However, to optimize the properties of the nano-antenna, and in particular the degree of field enhancement, it is crucial to carefully control the fabrication process. The fabrication technique should reproducibly meet several criteria: (i) for optimal performance and spectral tunability, dimensions should be controlled in the 10 nm size range[2] with sub-10 nm gap size. (ii) Ideally, also morphology and crystallinity of the antenna materials should be well-controlled[3]. And, (iii) the technique should be applicable to a variety of substrate types and shapes.

Electron-beam induced deposition (EBID) of a carbon-based etch mask has been shown to be a promising technique for nano-antenna fabrication[4,5]. With EBID, mask control well below 10nm is possible[6]. Also, antenna fabrication on the tip of a fibre has been demonstrated[4]. However, challenges remain in using EBID etch masks to control the gap, roughness in the top surface after Ar sputter etching, and removal of the mask material. Here, we demonstrate a modified procedure, using a Cr sacrificial layer in between metal and EBID mask. Using focused electron beam exposure, the precursor gas, $MePtCpMe_3$, is decomposed leading to deposition of Pt and C on the Cr sacrificial layer, see Figure 1. By adjusting the exposure procedure, we achieve sub-10 nm gap spacing. The EBID masks are sputter etched with Argon ions to transform the mask to the underlying Cr and Au layers. A Cr wet etch removes EBID mask and sacrificial layer, leaving a smooth upper Au surface. In this way half-wave antennas with sub-10 nm gap sizes are made, see Figure 2. Using this method we fabricated optical antennas from deposited Au films on both Si and ITO substrates.

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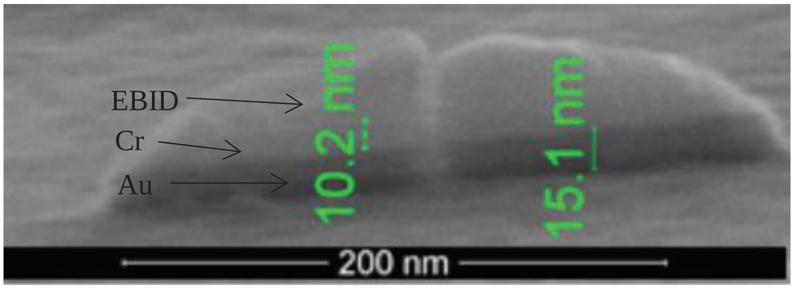

Figure 1: An 85 degree tilted SEM image of an antenna after Argon ion sputtering.

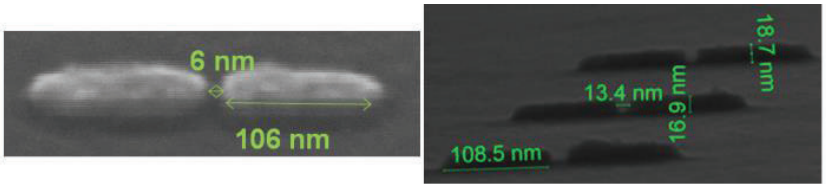

Figure 2: Antennas made of Au deposited on a Silicon substrate under 45 degrees (left) and 85 degrees (right).