DALI: DNA-assisted Lithography for Plasmonic Nanostructures

Boxuan Shen[1,2], Veikko Linko[2], Kosti Tapio[1], Siim Pikker[1], Tibebe Lemma[1], Ashwin Gopinath[3], Kurt Gothelf [4], Mauri Kostiainen[2] and Jussi Toppari[1]

[1] *Nanoscience Center and Department of Physics, University of Jyväskylä, Finland*
[2] *Biohybrid Materials, Department of Bioproducts and Biosystems, Aalto University, Finland*
[3] *Department of Bioengineering, California Institute of Technology, Pasadena, California, USA*
[4] *Department of Chemistry and Centre for DNA Nanotechnology, iNANO, Aarhus University, Denmark*
Email: j.jussi.toppari@jyu.fi

Programmable self-assembly of nucleic acids enables the fabrication of custom, precise objects with nanoscale dimensions, which can be further harnessed as templates to build novel materials and nanodevices with diverse functionalities [1]. Metallic nanostructures are widely used and explored because of their unique optical properties, such as selective field enhancement via plasmonic resonances, and their potency to serve as components of novel metamaterials [2]. However, the currently available fabrication techniques are not feasible for creating complex and sufficiently small metallic shapes for metamaterials functioning at the visible wavelength range. The common wet chemical methods merely yield geometrically limited structures, whereas the standard lithography that allows arbitrary shapes does not provide the required spatial accuracy. Here the DNA nanotechnology would enable many new possibilities. However, approaches to transfer the spatial information of DNA constructions to metal nanostructures remain a challenge.

We have developed a DNA-assisted lithography (DALI) method that combines the structural versatility of DNA origami with conventional lithography techniques to create discrete, well-defined, and entirely metallic nanostructures with designed plasmonic properties [3]. DALI is a parallel, high-throughput fabrication method compatible with transparent substrates, thus providing an additional advantage for optical measurements, and yields structures with a feature size of ~10 nm. We demonstrate its feasibility by producing metal nanostructures with a chiral plasmonic response and bowtie-shaped nanoantennas for surface-enhanced Raman spectroscopy. We envisage that DALI can be generalized to large substrates, which would subsequently enable scale-up production of diverse metallic nanostructures with tailored plasmonic features.

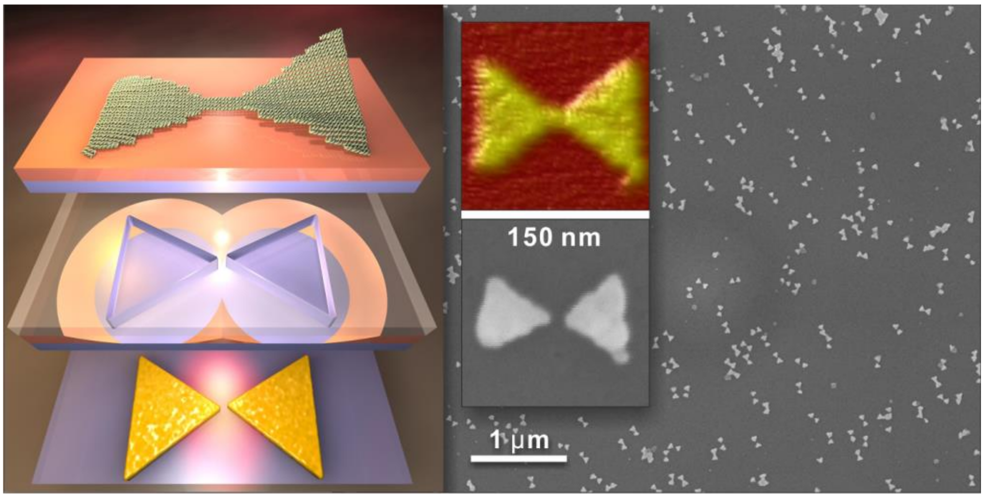

Figure 1: Schematic presentation of the DALI process. AFM image of a bowtie origami on a silicon surface and SEM image of a ready plasmonic bowtie antenna. Large surface covered with metallic bowties from a single run.

Funding by the Academy of Finland, Jane and Aatos Erkko Foundation, the Finnish Cultural Foundation, the Finnish Academy of Science and Letters, the Emil Aaltonen Foundation, and the U.S. Office of Naval Research is greatly acknowledged. The work was carried out under the Academy of Finland Centres of Excellence Programme (2014–2019).

References

[1] M.R. Jones, N.C. Seeman, C.A. Mirkin, Science 2015, **347**, 1260901; N.C. Seeman, H.F. Sleiman, Nature Rev. Mat. 2017, **3**, 17068; N. Liu, T. Liedl, Chem. Rev. 2018, **118**, 3032-3053.
[2] V. M. Shalaev, Nat. Photonics 2007, **1**, 41–48; Z. Wang, et al., Nanotechnology 2016, **27**, 412001.
[3] B. Shen, V. Linko, K. Tapio, S. Pikker, T. Lemma, A. Gopinath, K. V. Gothelf, M. A. Kostiainen, J. J. Toppari, Science Adv. 2018, **4**, eaap8978.