Accurate transfer of individual nanoparticles onto single photonic nanostructures

J. Redolat\textsuperscript{1}, M. Camarena-Pérez\textsuperscript{1}, A. Griol\textsuperscript{1}, M. Kovylina\textsuperscript{1}, A. Xomalis\textsuperscript{2,3}, J. J. Baumberg\textsuperscript{2}, A. Martínez\textsuperscript{1} and Elena Pinilla-Cienfuegos\textsuperscript{1*}.

\textsuperscript{1} Universitat Politècnica de València, Nanophotonics Technology Center, Valencia E46022, Spain
\textsuperscript{2}NanoPhotonics Centre, Cavendish Laboratory, Department of Physics, JJ Thompson Avenue, University of Cambridge, Cambridge CB3 0HE, United Kingdom
\textsuperscript{3}Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Mechanics of Materials and Nanostructures, Thun, Switzerland

Controlled integration of metallic nanoparticles (NPs) onto photonic nanostructures enables realization of complex devices for extreme light confinement and enhanced light-matter interaction. Extreme light confinement can be achieved combining Nanoparticle-on-Mirror (NPM) nanocavities \([1-2]\), with the light manipulation capabilities of micron-scale metallic antennas and/or photonic integrated waveguides \([3]\). However, metallic NPs are usually deposited via drop-casting, which prevents their accurate positioning. Here we present a methodology for precise transfer and positioning of individual NPs onto different photonic nanostructures. The method is based on soft lithography printing that employs elastomeric stamp-assisted transfer \([4]\), of individual NPs onto a single nanostructure. It can also parallel imprint many individual NPs with high throughput and accuracy in a single step. Raman spectroscopy confirms enhanced light-matter interactions in the resulting devices. Our method mixes top-down and bottom-up nanofabrication and shows the potential of building complex photonic nanodevices for applications ranging from enhanced sensing and spectroscopy to signal processing.

Figure 1. a) Schematic parallel stamp-assisted printing method. b) Meniscus formation between the stamp protrusion and sample. c) BPT Functionalized lithographed Au sample with NP attached. d) Optical image of a Au/BPT disk array after single-step NP transfer. Red arrows show NP positioning.

References

[1] Ciraci, C.; Hill, R. T.; Mock, J. J.; Urzhumov, Y.; Fernández-Dominguez, A. I.; Maier, S. A.; Pendry, J. B.; Chilkoti, A.; Smith, D. R. Probing the Ultimate Limits of Plasmonic Enhancement. \textit{Science} \textbf{2012}, \textit{(80.-)}, 337 (6098), 1072–1074.

[2] Baumberg, J. J.; Aizpurua, J.; Mikkelsen, M. H.; Smith, D. R. Extreme Nanophotonics from Ultrathin Metallic Gaps. \textit{Nat. Mater.} \textbf{2019}, \textit{18} (7), 668–678.

[3] Vázquez-Lozano, J. E.; Baumberg, J. J.; Martínez, A. Enhanced Excitation and Readout of Plasmonic Cavity Modes in NPoM via SiN Waveguides for On-Chip SERS. \textit{Opt. Express} \textbf{2022}, \textit{30} (3), 4553.

[4] Cavallini, M., Gentili, D., Greco, P., Valle, F. & Biscarini, F. Micro-and nanopatterning by lithographically controlled wetting. \textit{Nat. Protoc.} \textbf{2012}, \textit{7}, 1668–1676.

The authors acknowledge funding from the Spanish State Research Agency (Grant No.PID2021-24618NB-C21) and E.P.-C acknowledges funding from Generalitat Valenciana (Grant No. SEJIGE\textsuperscript{NT}/2021/039).