Physics and Nanosciences - PhD XXXVII cycle - Annual report - 09/2022 - German Lanzavecchia

Tutors: Roman Krahne, Denis Garoli

Research activity

Project DNA-FAIRYLIGHTS

The research activity has conducted within the project DNA-FAIRYLIGHTS, which aims to develop the concept of DNA data storage by decorating DNA molecules with a sequence of metallic nanomaterials with defined optical responses. Therefore, plasmonic and light-emitting particles with distinct optical responses arranged along the DNA strand will allow multiplexed data encoding and direct optical and electrical readout.

DNA data storage.

An extensive literature research was conducted for review paper: "Novel approaches to DNA data storage: Challenges and prospects", Doricchi, A.; Platnich, C.; Gimpel, A.; Horn, F.; Earle, M.; Lanzavecchia, G.; Cortajarena, A.; Liz-Marzán, L.; Liu, N.; Heckel, R.; Grass, R.; Krahne, R.; Keyser, U.; Garoli, D.
Status: Re-submitted after referees' reviews, ACS Nano

Nanofabrication

Fabrication of chips with Silicon Nitride membranes of different sizes. Masks have been designed to produce 150 to 500 µm squared membranes on different depth SiN/Si wafers. Membrane chips are fabricated via spin coating photoresist, UV exposure with mask, reactive ion etching and wet etching, cutting of the chips, optimizing the shape and dimensions for different applications, such as fluidic cells, and electron microscopy.
Nanopore and nanopore array fabrication using FIB on gold coated SiN membranes, varying the current to obtain different pore diameters. Markers are drilled onto the membrane in order to get resonating structures according to the wavelength of incident light, and for easy localization of nanopores under the microscope.
Hollow pillars (single and arrays) are prepared with FIB on SiN membranes prepared with a layer of photoresist and coated with gold, following oxygen plasma and developing with acetone.
Preparation of ultra clean glass coated with gold for optical analyses of single particles. Ultra clean areas marked with circular patterns, and passivated with a layer of Al_2O_3.

Electrical measurements

Implementing the use of a portable device consisting of a nanofluidic cell, Ag/AgCl electrodes, LEDs (red/green/blue), circuitry and analysis software manufactured by IC elements (DNA FAIRYLIGHTS partner). Gaskets made in PDMS were fabricated to fit inside the nanofluidic cell and secure the chip with the nanopore to ensure no leakage of fluid.
Applying different steps in voltage and measuring the current through the nanopore we are able to estimate the conductance through the nanopore and estimate its diameter. In order to reduce the capacitive noise, we implemented a reduced area coated with gold, passivation with a dielectric, and treatment with piranha solution. Experiments were performed also with LED lights turned on, observing an increase in the signal which is enhanced by plasmonic heating inside the nanopore.

Metal growth inside nanopores

We studied a method to produce nanopillar arrays based on the ability of metallic rings to confine and enhance the electromagnetic field in their inner part. The E-field enhancement inside the ring is used for metal localized nucleation and growth resulting in hole shrinking down to few nanometers.

The samples were exposed under white light illumination (Xe lamp, 50 W), and under red light (638 nm laser, 3mW) while immersed in $AgNO_3$ or $HAuCl_4$ solutions for a total duration of 10 up to 60 minutes in order to investigate the velocity of growth. The deposition is stopped by rinsing the sample with isopropanol and drying under N_2 flow. Metallic growth is then controlled on SEM. EDX analyses have been performed in order to verify the local deposition of silver.

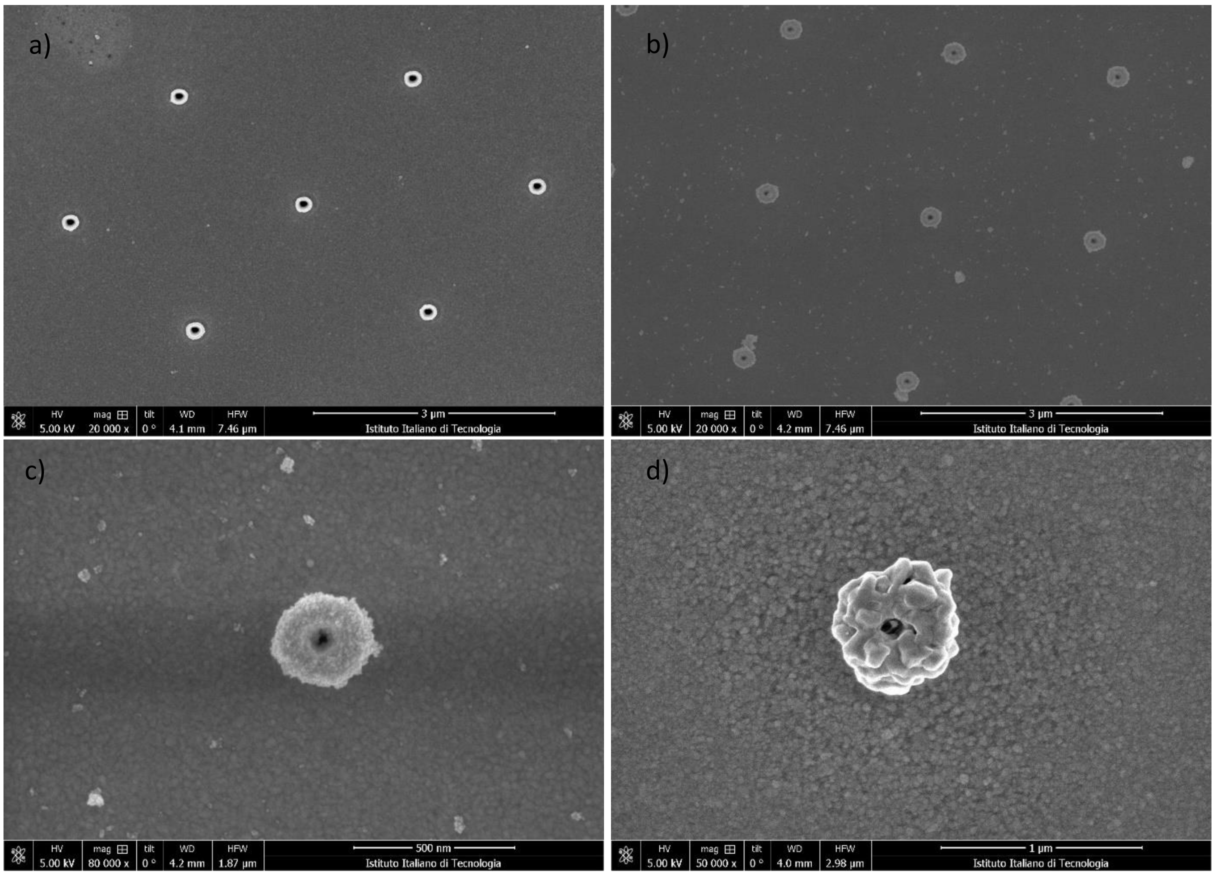

Fig. 1. a) Nanopillar array as prepared and b) after 45 min exposure in $AgNO_3$. c) Detail of a pillar after silver deposition and d) single pillar after gold deposition.

Same procedures were carried out with single pillars, as well as nanopore and nanopore arrays, obtaining similar results with respect to the metallic growth. In the case of single pillars, the rate of deposition is much faster. Electrical measurements on the single antennas and the diameters were calculated with good agreement to that measured with SEM, observing the corresponding reduction in the conductance of the pillar.

Optical Setup

Design and mounting of a setup for optical measurements for translocating light emitting particles through nanopores. The setup was built using an inverted microscope. Illumination comes from a laser at 473 nm, which is directed to the sample through a series of mirrors, beam expander, diaphragm and filter. Then the signal is collected and separated in three different ranges of wavelengths to three APDs, by means of dichroic mirrors at 490, 567 and 650 nm.

Courses

Atomic Force Microscopy - Exam passed
Electronics and data acquisition
Observational Astronomy