Surface structure enhanced optoelectronic properties of nanofibers

A PhD project by Oksana Kostiučenko.

Supervising by Horst-Günter Rubahn, Heinz Sturm, Morten Madsen and Jacek Fiutowski. 


Motivation: the optical properties of sub-wavelength metal nanostructures and organic nano-aggregates receive great interest in different fields of research, for instance in plasmonics, photonics, optoelectronics, because of inherent strong electromagnetic nonlinear response. Such a distinctive optical behavior is mainly caused by the geometrical lighting rod effect and excitation of localized surface plasmons (LSPs) i.e. resonant collective electron oscillations associated with optical resonances occurring on the individual metal nanostructure, which depend sensitively on the excitation wavelength. Moreover, resonant interactions between structures arranged in a periodic array may lead to further enhancements effects, i.e. for metal nanostructures placed on a metal surface. Tuning the array periodicity leads to resonant excitation of surface plasmons polaritons (SPPs).

The overall goal of this PhD project is to tailor the optoelectronic properties of one-dimensional semiconducting organic nano-aggregates using nano- and microstructured surfaces. For that, recently achieved experience in generating plasmonic active surface structures, characterization of electromagnetic surface fields, growth and transfer of organic nanoaggregates will be employed.

A success criterium for the project is the observation of a decrease of the threshold for second harmonic generation or lasing in one-dimensional nanoaggregates. 

Project execution:
the initial fabrication step of plasmonic active structures will be based on the lift-off technique, applying high-resolution EBL (electron beam lithography) at the Nanosyd cleanroom for preparing field enhancing nanostructures

FIGURES:
(a) Schematic view of fabrication steps: (1) and (3) Electron beam evaporation of 70 nm and 55 nm of Au respectively; (2) Spin coating of PMMA, EBL and development of exposed resist; (b) optical microscope image x50 of organic CNHP4 nanofibers placed on fabricated nanostructured array; (c) Experimental setup of Laser Scanning Microscope (LSM); (d) second harmonic signal generated by local field enhancement: measured reflection spectrum from nano-squares, nano-triangles array and CNHP4 nanofibers placed on top of nanostructures, excited with the pulse wavelength centered at 780 nm.

Plasmonic substrates will be covered with different thickness of DLC coatings at Institute of Materials Science of Kaunas University of Technology (Kaunas, Lithuania) and investigated in terms of tribology AFM measurements at BAM (Berlin, Germany). Wear resistance is going to be measured of DLC (diamond like carbon) coated and uncoated plasmonic substrates.

A confocal Raman/AFM configuration will be used in combination with plasmonic nanostructures to further monitor and apply the achieved field enhancements.
A femtosecond LSM (laser scanning microscopy) will be used to characterize the optical (linear and nonlinear) response of these structures. The LSM characterization of the optical near field will be performed with the help of a recently developed “imprint” technology, where a thin PMMA (Poly(methyl methacrylate)) film is deposited on the structures, which is then deformed according to the surface electromagnetic field distribution and monitored with the help of a SEM (scanning electron microscopy). Since this is a quantitative method that leaves the metallic structures unaffected and useful for further applications, it can be used to optimize the surface fields via structural and material changes.