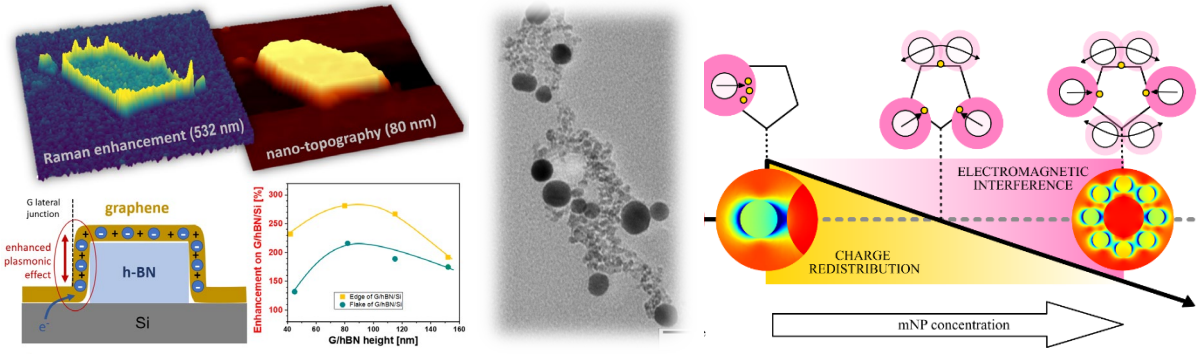
Visible frequency plasmonic effects in graphene and diamond heterostructures

Prof. Bohuslav Rezek et al.

Faculty of Electrical Engineering, Czech Technical University in Prague, Czechia

Control of plasmonic properties has become essential part of many current technologies from biomedicine to photocatalysis and energy conversion. In this presentation we will show our correlative microscopy study of high quality single layer CVD graphene that is combined with hexagonal boron nitride (G/*h*-BN) for controlling graphene opto-electronic properties. We observed highly enhanced Raman intensity along the G/*h*-BN edge (10 – 150 nm, with maximum at 80 nm) under visible light excitation. It was unexpected as graphene typically exhibits plasmonic oscillations in infrared frequency range. The enhancement arises only on p-type Si substrate whereas on SiO_2 substrate the signal is suppressed. We will describe a model of localized concentration of electrons in graphene in perpendicular orientation at the h-BN edge. Such mechanism is supported by microscopic optical absorption and AFM-in-SEM analysis showing enhanced electron contrast at the edge. We also introduce physics-based FEM simulations of radio-frequency field distribution on the heterostructures, which shows the field focusing and fully corroborates the experimental observation. We will discuss how these results motivate novel ideas for plasmonic device designs combining graphene with diamond and oxide materials. We will also introduce a novel direction where plasmonic enhancement at stable frequency can be achieved by spontaneous assembly of hydrogenated or oxidized HPHT and detonation nanodiamond complexes with silver or gold nanoparticles.



Acknowledgements. Collaboration with colleagues from AIST and NIMS on this topic is gratefully appreciated. JSPS Invitation Fellowship No. 25003154 is kindly acknowledged for financial support of the Japanese-Czech collaboration. The latest results can be found in Carbon 219 (2024) 118836 and Diam. Relat. Mater. 154 (2025) 112211. The research makes use of the TACOM laboratory for correlative microscopy (https://tacom.fel.cvut.cz/en/).

Biography

Bohuslav Rezek is a professor of Applied physics and the head of Physics dept. at the Faculty of Electrical Engineering of the Czech Technical University in Prague.

He graduated from Physics at the Faculty of Mathematics and Physics at the Charles University in Prague in 1996 and he continued at the Czech Academy of Sciences (CAS) in the group of Dr. Jan Kočka with PhD study on charge transport in amorphous and microcrystalline silicon with high lateral resolution by using scanning probe techniques. During his PhD he also made several research stays in the group of Prof. Martin Stutzmann at the Walter Schottky Institute, Technical University Munich. There he worked with Dr. Christoph Nebel on development of large grain silicon thin films using interference laser crystallization of amorphous silicon layers and on their investigation by laser beam induced currents with a sub-micrometer lateral resolution, with a special view to optical and electronic properties of grain boundaries.

After receiving PhD degree in 2001, he continued in the group of Prof. Stutzmann as a postdoctoral researcher on the project for diamond devices and sensors where he focused on a study and modification of hydrogen terminated diamond surfaces and their electrolytic interfaces. In 2002 he joined the Nanotechnology Group at the Swiss Federal Institute of Technology, where he worked on guided assembly of colloidal nanoparticles at solid state surfaces. Since 2004 he worked at the Diamond Research Center of AIST in Tsukuba, Japan, doing research on surface (bio)-functionalized diamond devices.

In 2006 he became research group leader and Purkyně Fellow at the Institute of Physics CAS in Prague, Czech Republic. In 2013 he habilitated in the field of Applied physics. Since 2015 he became a head of Physics dept. at the Faculty of Electrical Engineering of the Czech Technical University in Prague. In 2019 he became full professor there. Among other duties he chairs the doctoral study program of Applied Physics and governmental evaluation panel of Natural Sciences.

His research team is focused on nano-interfaces of semiconductors and organic materials towards opto-electronic and bio-electronic applications. His main interests lie in characterization and modification of material, electronic, and chemical properties by local probe techniques as well as in assembly of organic and inorganic nanostructures. Experimental studies are complemented by simulations on atomic and molecular scale.

He is the author or co-author of over 200 scientific articles in international peer-reviewed journals that were cited more than 4000 times as well as of book chapters (10) and patents applications (8). More details can be found at https://scholar.google.cz/citations?user=mb1IXcUAAAAJ.