Combined Scanning probe microscopy and micro/nano Raman studies of modern nanostructures

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In this report, we demonstrate various applications of confocal Raman/fluorescence microscope integrated with Atomic Force Microscope (AFM). We report on "classical" applications of such combination, when 2D AFM and confocal Raman maps are acquired simultaneously from the *same* part of the sample, but "independently" one from another. Physical characterization and modification capabilities of AFM merge with chemical resolution of confocal Raman microscope and general capabilities of optical microscope to provide complete information about sample investigated. Diffraction limited resolution of 2D Raman maps is 200 nm. We demonstrate results on various promising nanoelectronics materials: graphene flakes, carbon nanotubes, semiconductor nanowires etc.

The ultimate goal of integrating AFM with Raman/fluorescence spectroscopy is to break diffraction limit and to bring spatial resolution of optical methods down to resolution of AFM (a few nm). We describe different ways of using light interaction with the apex of AFM cantilever to produce an optical signal originated from a substantially *subwavelength* sample area ($<50\times50$ nm^2) located *right below* apex of AFM probe. By scanning the AFM probe along the sample, getting 2D maps of Raman or fluorescence signals with subwavelength resolution (down to a few dozens of nm) is possible. We focus on the results of Tip Enhanced Raman Scattering (TERS) experiments – where Raman signal from narrow sample area below the metallized AFM tip is resonantly enhanced due to interaction with plasmons localized at the tip apex. The resulting resolution of 2D Raman mapping is about 60 nm that goes far beyond the optical diffraction limit. TERS data on carbon nanotubes, fullerenes, graphene and stressed Si structures is presented. We discuss experimental procedure and strict setup requirements for TERS experiments. Special emphasis is put on the difference between transmission (transparent samples) and reflection (opaque samples) TERS geometries.