Characterization of nanostructured materials, biological specimens, and their interaction by means of correlative optical imaging in the far-field and near-field regimes

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Introduction: CMMIP-UPB has recently developed a multimodal system capable to collect optical data sets on overlapping field-of-views by several techniques operating in the far-field and near-field regimes, and to place these into a topographic context using Atomic Force Microscopy. The contrast mechanisms of the incorporated imaging modalities provide complementary information, which plays an important role in facilitating data understanding and interpretation. Scattering-type Scanning Near-Field Optical Microscopy (s-SNOM), one of the available techniques, can be used to extract quantitative information over the real and imaginary parts of the dielectric function at spatial resolutions beyond the diffraction barrier [1]. In biomedicine such information can provide an estimate over various aspects with physiological/pathological relevance, such as the concentration of cell constituents, or cell intoxication with exogenous agents, while in materials science it can enable a better understanding of nanostructured specimens and the development of novel applications. The characterization of carbonaceous materials formed in combustion, such as nanoparticles and primary soot, can also benefit of these possibilities offered by s-SNOM. A precise understanding of how their dielectric and optical properties correlate with size may lead to developing sensing technologies [2] with capabilities beyond the current state-of-the-art.

ARCHITECTURE

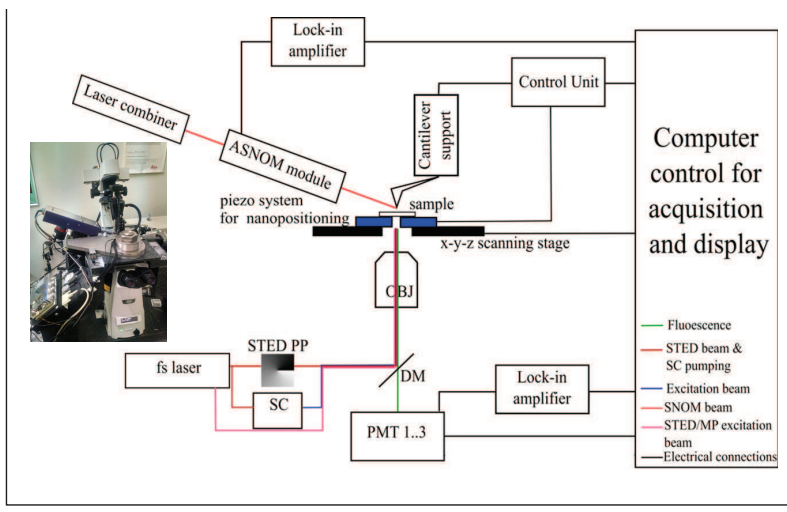

Fig. 1: Schematic diagram of the multimodal far-field ↔ near-field imaging system in development at CMMIP-UPB.

Top module, **Atomic Force Microscopy (AFM)** and **Apertureless Scanning Near-Field Optical Microscopy (ASNOM)** in three work-modes: (1) scattering-type Scanning Near-Field Optical Microscopy (s-SNOM), (2) Second Harmonic Generation Scanning Near-Field Optical Microscopy (SHG-SNOM) and (3) Fluorescence Apertureless Scanning Near-Field Optical Microscopy (FASNOM)

Bottom module, **Laser Scanning Microscopy (LSM)**: (1) Confocal Laser Scanning Microscopy (CLSM), (2) Multiphoton Laser Scanning Microscopy (MPLSM), (3) *pump & probe nanoscopy (work in progress).*

ASNOM advantages	LSM advantages
-nanoscale optical resolution	-3D optical sectioning
-label-free contrast mechanisms	-non-invasive imaging of biological species
-quantitative assessment of the dielectric function	-non-linear effects with femtosecond lasers
-on-the-fly correlation with topography	-high acquisition speed

APPLICATIONS

Nanostructured materials

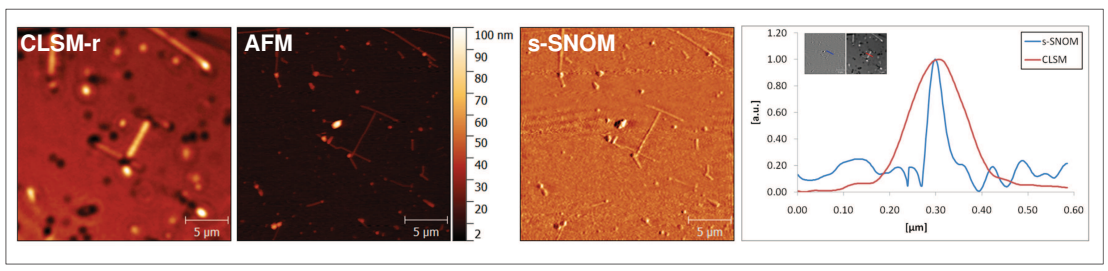

Fig. 2: Ag nanorods imaged with CLSM – reflection, AFM and s-SNOM (amplitude).

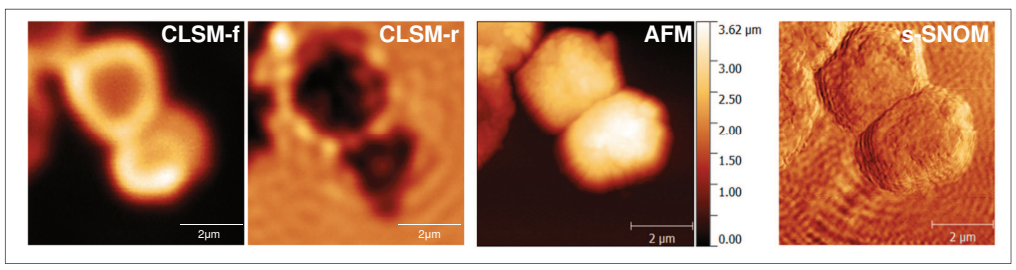

Fig. 3: Fluorescent labeled nanostructured polyelectrolyte capsules imaged with CLSM in fluorescence and reflection, AFM and s-SNOM [3].

Combustion generated particles

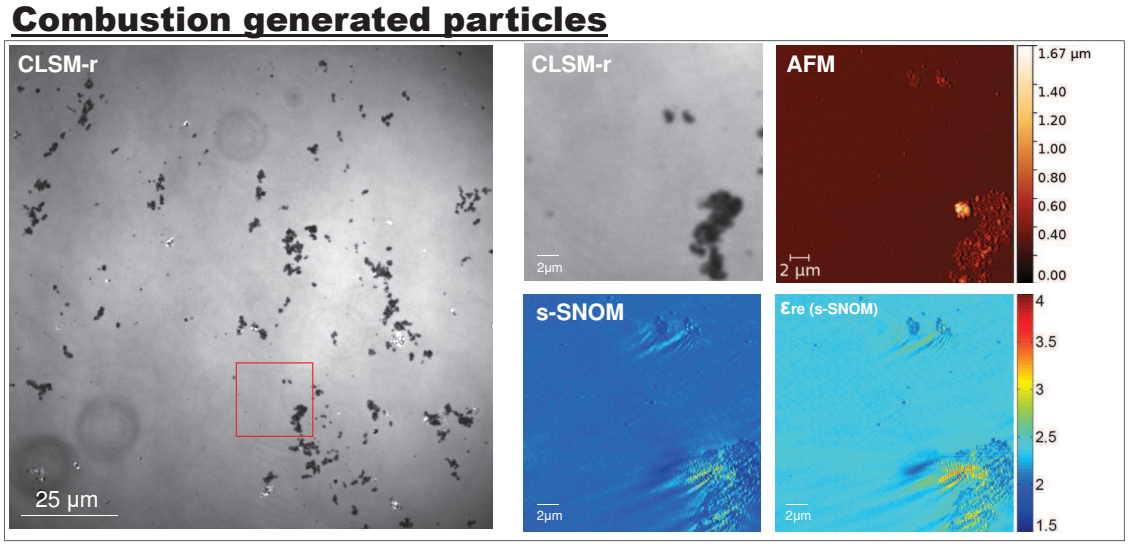

Fig. 4: Combustion generated particles (CGPs) deposited on a glass substrate positioned in front of the tail-pipe of a gasoline engine car (Mazda 3 2015, 1998cm^3, Euro 5) imaged with CLSM – reflection, AFM and s-SNOM (amplitude). A map of the real part of the dielectric function, ε_{re}, is built based on s-SNOM data [1] (calculation of ε_{im} is also possible).

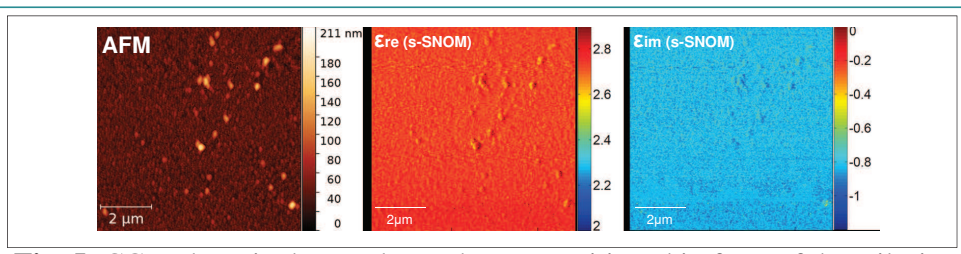

Fig. 5: CGPs deposited on a glass substrate positioned in front of the tail-pipe of a diesel engine car (Renault Clio 2005, 1498cm^3, Euro 4) imaged with AFM and s-SNOM (dielectric function map, ε_{re} & ε_{im})

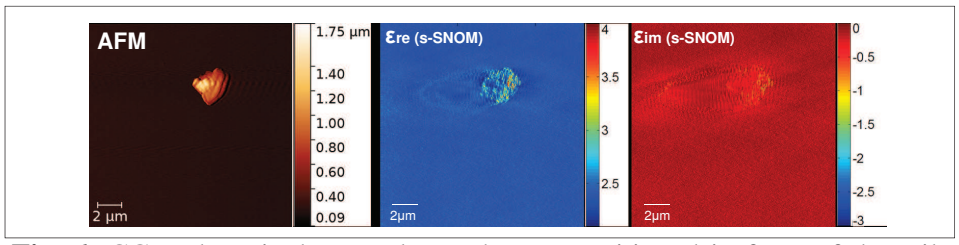

Fig. 6: CGPs deposited on a glass substrate positioned in front of the tail-pipe of a gasoline engine car (Mazda 3 2004, 1598cm^3, Euro 4) imaged with AFM and s-SNOM (dielectric function map, ε_{re} & ε_{im})

Biological specimens

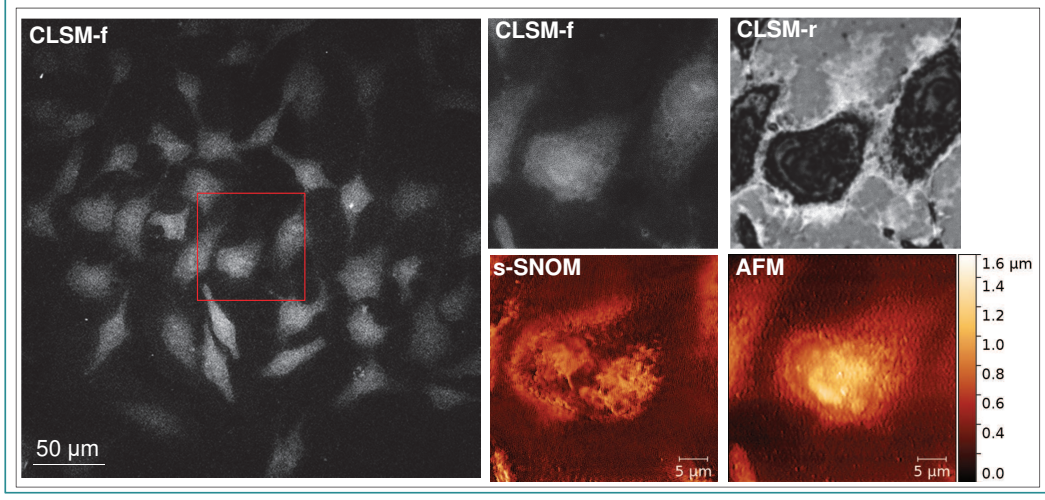

Fig. 7: Giemsa stained HeLa cells treated with Au nanoparticles imaged with CLSM (fluorescence + reflection), s-SNOM (amplitude) and AFM.

Acknowledgments:

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References:

[1] High-resolution quantitative determination of dielectric function by using scattering scanning near-field optical microscopy, D.E. Tranca, S.G. Stanciu, R. Hristu, C. Stoichita, S.A.M. Tofail, G.A. Stanciu, *Scientific Reports*, 5, 11876 (2015)
[2] D'Anna, A., 2009. Combustion-formed nanoparticles. *Proceedings of the Combustion Institute*, 32(1), pp.593-613.
[3] Combined Far-field, Near-field and Topographic Imaging of Nano-Engineered Polyelectrolyte Capsules, S.G. Stanciu, D.E. Tranca, C. Ruggiero, G.A. Stanciu, A. Antipov, R. Hristu, L. Pastorino, *Materials Letters*, 183, 105-1028 (2016)