Objectives

The goal of the project is preparation and physicochemical characterization of the bifunctional luminescent-plasmonic core/shell nanomaterials, based on lanthanide nanoparticles and gold nanostructures. Such materials are going to be composed of luminescent (exhibiting emission of visible light after excitation with UV or IR light), lanthanide doped inorganic nanocrystals (1-100 nm), coated with amine or thiol modified silica shell. The external shell will be decorated with gold nanostructures revealing plasmonic effects (related to the light interaction with valence electrons of metals). The influence of plasmonic metal nanostructures for the luminescence of lanthanide nanoparticles, and vice versa will be investigated. The final bifunctional nanomaterials are going to be used in multimodal imaging/detection, thanks to their luminescence and plasmonic activity.

Basic research to be carried out

The project will be devoted to the synthesis of lanthanide-doped luminescent nanostructures, their coating with $–NH_2$ or –SH modified silica shell and surface decoration with gold nanoparticles, leading to the formation of bifunctional luminescent-plasmonic core/shell nanomaterials.

The inorganic luminescent phase of such nanomaterials will be composed of nanoparticles based on the rare earth elements, because of their desired spectroscopic properties (multicolour emission, long luminescence lifetimes, large stokes shifts, narrow emission bands, photostability, etc.). The new nanocrystalline matrices (simple and complex fluorides, vanadates, phosphates and oxides) doped with lanthanide ions will be synthesized, in order to obtain and select the brightly illuminating, stable, small and uniform nanoparticles. The selected luminescent nanoparticles will be coated with amine and thiol modified silica shell. The optimal shell thickness will be determined, in order to provide appropriate distance between lanthanide and gold nanoparticles. The second active component will be metal nanoparticles exhibiting plasmonic activity for surface enhanced Raman scattering (SERS). The metal nanoparticles (Au) will be conjugated to the amine/thiol modified silica shell (e.g. $LnF_3/SiO_2/SH/Au$, $LnF_3/SiO_2/NH_2/Au$), thanks to the strong affinity of –SH and $–NH_2$ groups to gold atoms. Due to the presence of two different functional phases within a single product, the synthesized innovative nanomaterials will be unique bifunctional nanostructures, exhibiting simultaneously multicolour luminescence and plasmonic effects.

The concentration of surface functional groups, shell thickness, composition and crystallinity of core, as well as morphology, particles size/shape distribution and homogeneity of the deposited gold nanoparticles will be deeply investigated. In order to study the properties of the nanomaterials obtained, they will be examined by the means of powder X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM), spectrofluorometry, UV-Vis and FT-IR spectroscopy, elemental analysis, surface properties measurements (surface area and porosity), dynamic light scattering (DLS) and other analytic techniques. The particles size distribution will be determined on the basis of TEM and DLS measurements. The luminescent–plasmonic nanomaterials will be also used as an active bases for the measurements of surface enhanced Raman scattering (SERS). The typical organic compounds using for the determination of enhancement level of Raman scattering will be adsorbed on the surface of the nanomaterials obtained, and the results of SERS measurement will be compared with currently used planar compounds.On the basis of the performed research (luminescence spectroscopy and SERS measurements), the impact of gold nanostructures for the lanthanide nanoparticles, and vice versa will be determined.

Reasons for choosing the research topic

There is very little literature data about the bifunctional nanomaterials based on lanthanide ions, exhibiting simultaneously plasmonic effects and luminescence. The novel luminescent-plasmonic nanomaterials which are going to be synthesized reveal altered photophysical properties in comparison to their bulk analogues. Such nanomaterials will be composed of luminescent lanthanide nanoparticles coated with amine and thiol modified silica shell. The external shell will be decorated with gold nanoparticles exhibiting plasmonic activity.

The synthesized luminescent-plasmonic nanomaterials will be applied as an active base (carrier) in the studies of surface enhanced Raman spectroscopy (SERS), namely the identification of the structure of organic compounds adsorbed on the surface of such nanomaterials. Because the obtained nanomaterials will be bifunctional, they allow simultaneous luminescent imaging and detection of the trace amount of organic compounds and biological structures (multimodal imaging).

These features will facilitate and shorten the analysis time, which is crucial in many scientific, medical and industrial applications. That is why, the proposed research concerning the synthesis and physicochemical analysis of such innovative bifunctional nanomaterials, provide a lot of new experimental data and give substantial contribution to the actual state of knowledge, as well as accelerate the scientific and industrial progress by the development of material engineering, optoelectronics, trace analytics, nanotechnology and nanomedicine. The proposed sophisticated nanomaterials can be potentially applied in multimodal imaging, analytic chemistry, detection of trace substances or impurities, forensics (hard to imitated/fabricated protections of documents), targeted therapies, as new light sources (generation of white light), etc.