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ROLE OF PHOTOLUMINESCENT NANOPARTICLES IN OPTICAL IMAGING

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ABSTRACT

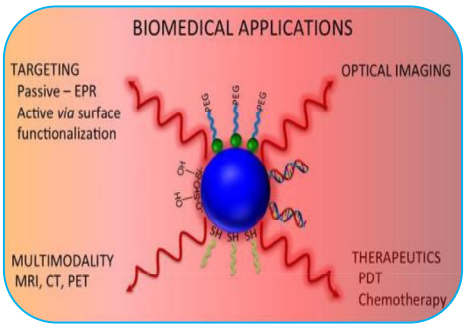

Photo luminescent nanoparticles are the key components of the biomedical research. Their versatile surface functionalization and adaptable optical properties are some of the remarkable features allowing their implementation for Bioimaging. Nanoparticles are characterized by large surface to volume ratios, favoring the loading of therapeutic agents, while their targeting features allow their accumulation in tumor or inflamed tissues. Photo luminescent nanoparticles can combine the therapeutic effect with bioimaging capabilities. Their remarkable optical properties provide them with the potential in optical imaging as well as triggering photo chemical reactions in biological environment. Accordingly, research has been carried out for the fabrication of superior and biocompatible photo luminescent nanoparticles with controlled size and morphology, particularly semiconductor quantum dots (QD's), Lanthanide based up converting nanoparticles (Ln-UCNP'S), C-Dots, nanophosphors and gold nano particles. These are the building blocks for the fabrication of highly efficient multimodal imaging probes. The present paper deals with the optical properties of luminescent nano particles like quantum dots (QD's), Lanthanide based up converting nano particles (Ln-UCNP'S), C-Dots, nanophosphors and gold nanoparticles. The paper also discusses the biomedical applications of luminescent nano particles with special reference to optical imaging.

KEYWORDS : *Nano particles, Photo luminescent nanoparticles, optical imaging.*

1.INTRODUCTION

Photo luminescent nanoparticles can combine the therapeutic effects with bioimaging capabilities. Their remarkable optical properties provide them with the potential in optical imaging. Accordingly, the research has been carried out worldwide leading to the fabrication of superior and biocompatible photo luminescent nanoparticles with controlled size and morphology, particularly semiconductor quantum Dots (QD'S), Lanthanide based up converting (Ln-UCNP'S), C-Dots, nanophosphors and gold nanoparticles. These are the building blocks for the fabrication of high efficient multi modal imaging probes. Physio chemical properties and biocompatible properties play an important role in the interaction with biological entities. Photo luminescent nanoparticles are widely used in bio medical applications like drug targeting, optical imaging, photo dynamic therapy (PDT) and chemotherapy.

2. OPTICAL PROPERTIES OF PHOTO LUMINESCENT NANO PARTICLES

2.1 Quantum dots

These are fluorescent inorganic nano crystals with unique size dependent optical properties. High quantum yields, broad absorption spectra, tunable narrow emission bands and high photo stability are some of their outstanding optical properties. The physical dimension of QD is around 2 – 10nm, which is smaller than the exciton Bohr radius. The optical properties are directly related to the size of the QD. QDs photo luminescent is characterized by intermittent on – off states.

2.2 Lanthanide doped up converting nano materials (Ln-UCNP'S)

These have unique optical features. The optical properties of the Lanthanide ions can be attributed to the fact that the 4 f orbital are shielded thus minimally affected by the crystal field of the host lattice. Thus Ln^{3+} ions introduced as dopants in inorganic hosts shows narrow absorption and emission bands with long time excited states. Ln-UCNP'S can be excited using near-infra red (NIR) light and subsequently emit in the ultra violet, visible and NIR regions via the process of up conversion. The use of NIR light offers better penetration depth in tissues without imparting damage and avoiding auto fluorescence.

The up-conversion luminescence in (Ln-UCNP'S) is through excited states absorption (ESA), energy transfer up conversion (ETU) and photo avalanche. ESA involves the sequential absorption of two or more long wavelength photons, promoting the ion from the ground to an excited state, followed by the emission of one higher energy photon. ETU occurs via the transfer of energy between a donor-acceptor neighboring pair of ions followed by emission of the acceptor ion. The ETU mechanism is dependent on the overall dopant ion concentration and its efficiency is influenced by the choice of donors and acceptor ions as well as their respective concentration.

2.3 Luminescence Nano phosphors

The optical properties of persistent luminescence nano materials are based on the recombination of electrons and holes in semiconductor or insulator hosts. When the host is irradiated with a high energy excitation, electrons and holes are generated and are trapped in metastable states present in the host. Trapping sites may be formed either by the introduction of co-dopants (example lanthanides or transition metal ions) or the presence of impurities the excitation energy in the trapping sites can be stored for long periods of time and the release can be stimulated either thermally or optically. Luminescent nano phosphors are used in bio imaging to obtain images without excitation, eliminating auto fluorescence and improving the signal to noise ratio. Divalent and tri valent lanthanides and transition metal ions are used as dopants in host such as sulfides, oxy sulfides, silicates, nitrides, phosphates, aluminates, titanates, metal oxides and fluorides to obtain red and NIR luminescent materials

2.4 Carbon dots (C-DOT)

C -Dots have emerged as excellent nano carbon materials because of their outstanding properties like water dispersibility, high chemical stability and photo stability, low toxicity and ease of surface modification. They are composed of sp^2 carbon cluster with a high content of oxygen. The incorporation of other hetero atoms has also been explored in order to fine-tune their optical properties. The radiative recombination of surface confined electrons and holes play a major role in the emission. The overall optical behavior of C-Dots is characterized by the quantum confinement effect, emissive traps and recombination of excitons. The wave length of C-Dots emission is dependent on the wave length of excitation.

2.5 Gold nano particles

Gold is considered as plasma metal as it has free and highly mobile electrons with an equal number of fixed positive charges. They emit light through the radiative recombination of the exciton formed by the electrons in the S-P conduction band below the Fermi level and the holes in the d-bands

generated by optical excitation. Upon irradiating the surface of the plasma metal with electromagnetic waves, a collective quantized coherent oscillation of the free electron arises i.e., in resonance with the frequency of the incident photon. This phenomenon is known as surface Plasmon resonance (SPR). SPR can generate localized and intense optical fields with strong absorption of the incident light. The intensity and wave length of the SPR band obtained are dependent on the distribution of the electron charge density at nano particle surface, its morphology, size and the physio chemical properties of the surrounding medium.

3. BIOMEDICAL APPLICATION-OPTICAL IMAGING

Optical imaging is a powerful biomedical tool for early detection, screening and image guided therapies of various types of diseases. Photo luminescent nano particles will serve as optical imaging probes require excitation wave length that lie in biological optical transparency window (BOTW). In this region light has deeper penetration depth and reduce scattering at the same time auto fluorescence from tissue is minimized. QDs, Ln-UCNP'S, Gold nano particles are used for the selective detection of cells, for the elucidation of biological processes and for identifying intra cellular events. Targeting specific molecules in cells and tissues, both invitro and in vivo has been applied to identify molecular events. QDs have become the most popular nano material employed to investigate cellular structures and functions. Gold nano particles are also employed in cellular imaging. Their remarkable large absorption cross-section makes them suitable as contrast agents in multiphoton luminescence-based technique. Two photon absorption can be induced by the excitation of noble metal nano particles with a femto second pulsed laser in resonance with their surface Plasmon. Three photon luminescence is observed in metallic nano particles due to their large absorption capabilities. Ln-UCNP'S that may be excited by NIR radiation without requiring high intensity. Pulsed lasers have increased their popularity as cellular luminescent probes.

C-Dots exhibits strong two photon absorption allowing their applications for both one photon and two photon microscopies. Nonspecific and targeted imaging has been shown for C-Dots which have been up taken by multiple kinds of cells, including bacterial and fungal cells, Hela cells, fibro blast cells and stem cells. On the other hand, NIR emitting luminescent nano particles have also been applied in cellular imaging, their ability to undergo optical excitation before being incubated with the targeted cells provides high improvement to the signal-to-noise ratio. Photo luminescent nano particles have been evaluated as contrast agents for the invivo detection of tumors. The development of optical imaging contrast agents for the invivo detection of cancer is currently mostly focused on nano particles absorbing and emitting light within the BOTW. Persistent luminescence nano phosphorous were investigated for in vivo imaging of tumors

4. CONCLUSIONS

In this review, the optical properties of five luminescent nano particles like QDots, Ln-UCNP'S, C-Dots, Nano phosphors and Gold nano particles were discussed and their biomedical application with a special reference to optical imaging. The unique optical and physio chemical properties of luminescent nano particles contribute to make them highly attractive candidates for imaging, drug delivery, targeting, detection and therapy.

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