

# Rare earth doped upconverting Nanoparticles: Synthesis and application in Bio-Imaging

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## ABSTRACT

*Upconversion luminescence, a nonlinear process, which re-emits a photon at a shorter wavelength by the absorption of more than one photon, successively at longer wavelengths via long-lived intermediate energy states, is useful for important applications in various fields like fluorescence bio-imaging and lasers. This NIR-to-NIR up-conversion process provides deeper light penetration into biological specimen and results in high contrast optical imaging due to absence of an auto fluorescence background and decreased light scattering. Excitation at long wavelengths also minimizes damage to biological materials. Herein, we report, the different mechanisms responsible for the Upconversion process of rare-earth ( $Er^{3+}$ ,  $Ho^{3+}$ ,  $Tm^{3+}$ ) doped nanoparticle and methods that are used to synthesize and decorate up converting nanoparticle.*

**Keywords:-** Upconversion, Nanoparticles, chemical, etc.

## I INTRODUCTION

Upconversion is an optical process that involves the conversion of lower-energy photons into higher-energy photons. It has been extensively studied since mid-1960s and widely applied in optical devices. Over the past decade, high-quality rare earth-doped Upconversion Nanoparticles have been successfully synthesized with the rapid development of nanotechnology and are becoming more prominent in biological sciences. The main difference between the Upconversion Nanoparticles and other nonmaterial's is that they can emit visible light under near infrared irradiation. Upconversion nanoparticle (UCNPs), particularly lanthanide-doped nanocrystals, which emit high energy photons under excitation by the near-infrared (NIR) light. These nanoparticles have been found potential applications in many fields, including biomedicine and is found improved tissue penetration and higher photochemical stability as compared with traditional down-conversion fluorescence imaging. The unique Upconversion process of upconverting nanoparticles may be utilized to activate photosensitive therapeutic agents for applications in cancer treatment. Upconversion luminescence imaging in vivo is expected to be the next generation photoluminescence imaging technique since it provides high sensitivity and spatial resolution. Due to some special properties such as their multicolour emission, high brightness and long lifetime, lanthanide ions based luminescent nonmaterial have tremendous promise as indicators and photon sources for numerous application such as boilable, light-emitting devices, sensor technology, and low-threshold lasers. So it is very important to successfully prepare the rare-earth doped inorganic nanocrystals with good

dispensability in organic solvents and also prepare water soluble upconversion nanoparticle.

In the Up conversion phenomenon has been transition metals, actinides, but mainly in the rare earth elements, which contain the lanthanide (Ln) series, Yttrium, and scandium.  $Ln^{3+}$  ions have special  $4f^n 5d^{0-1}$  inner shell configurations that are well – shielded by outer shell and have unique energy level structures. The  $Ln^{3+}$  ions can exhibit sharp luminescence emission via intra-4f or 4f-5d transitions. These luminescence properties, as narrow bandwidth, long-time emission, and anti-stokes emission, they have been widely applied in lasers, solar cell, analytical sensors, optical imaging, and photodynamic therapy.

Most of the fluorescent materials are generally excited by ultraviolet (UV) or visible light, which may induce auto fluorescence and photo damage to biological samples, resulting in low signal-to-noise ratio and limited sensitivity. These limitations prompted the development of a new type of high-quality and well-shaped nonmaterial's known as up conversion nonmaterial's (UCNs [1-7].

Lanthanide-doped Upconversion (UC) nanophosphor are promising optical Contrast agents for biomedical applications due to their photo stability, sharp emission peaks, and long emission lifetime [8, 9]. For *in vitro* or *in vivo* imaging, the use of NIR excitation minimizes absorbance, scattering, and fluorescence from cells and tissues, allowing imaging against a dark background [13]. In contrast, commercially available labels, such as organic dyes and quantum dots, typically must be imaged against a background of Stokes-shifted tissue auto fluorescence induced by UV, blue, or green excitation [14]. In addition, because of the existence of real intermediate energy levels in

lanthanide ions, this Upconversion process can be much more efficient than in conventional multiphoton-absorption-induced fluorescence of organic dyes or quantum dots, where the intermediate levels are virtual.

Bio-imaging the term that covers the complex chain of acquiring, processing and visualizing structural or functional images of living objects or systems, including extraction and processing of image-related information. The upconversion nanoparticles used in bioimaging due to their small physical dimensions and biocompatibility, UCNPs can be easily coupled to proteins or other biological macromolecular systems and used in a variety of assay formats ranging from bio-detection to Cancer Therapy.

For bioimaging the Anti-Stokes luminescence offers key advantages over traditional down conversion emission observed with organic fluorophores. Bio-imaging advantage of UCNPs is their low background fluorescence and high signal-to-noise ratio.

Fluorescence targeted bio-imaging *in vivo* has proven very useful in tumour recognition and drug delivery

## II MOTIVATION FOR THE WORK

Lanthanide-doped upconversion-luminescent nanoparticles (UCNPs), have been very useful for *in vitro* and *in vivo* molecular imaging studies. In comparison with the conventionally used down-conversion fluorescence imaging strategies, the NIR light excited luminescence of UCNPs displays high photo stability, low cytotoxicity, little background auto-fluorescence, which allows for deep tissue penetration, making them attractive as contrast agents for biomedical imaging applications. In this review, we will mainly focus on the latest development of a new type of lanthanide-doped UCNP material and its main applications for *in vitro* and *in vivo* molecular imaging and we will also discuss the challenges and future perspectives.

New materials with high Biocompatibility and more intense emission spectra are needed to be developed so for deep tissue imaging. And also synthesis of water soluble UCNP, with functionalized surface by Ligand Engineering, with high emission intensity, synthesis of UCNP of narrow-size distribution with controlled shape.

## III CONCLUSION

The past decade a large number of scientists have investigated the potential application of UCNPs in bioimaging. A variety of Upconversion nanophosphor have been developed for bioimaging, and most of them are based on rare earth doped NaYF<sub>4</sub>. Other kinds of RE doped nanoparticles, such as NaGdF<sub>4</sub>, NaLaF<sub>4</sub>, Y<sub>2</sub>O<sub>3</sub>, GdF<sub>3</sub>, CeO<sub>2</sub>, LiNaF<sub>4</sub>, Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>, ZrO<sub>2</sub> and GdOF etc. have also been considered as excellent UCNPs in recent years due to their strong Upconversion luminescence intensity and good photo stability. But due to some limitation and drawbacks development of new upconversion nanoparticle is more important in application of bioimaging.

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