

POPULAR SCIENCE DESCRIPTION

Have you ever thought about how the health-care style would look like in future, or in another word, in which direction the medical treatment would develop? Non-invasive approach both for diagnostics and treatment is a dream and the ultimate goal of numerous scientists and engineers alongside of such thinking. Among others, fluorescence based biomedical techniques, largely due to their non-invasive merits, would occupy an essentially important place in future medical techniques. Imagine how elegant and delicate it would be, if you just shine light on the body, and the lesion in deep tissues would be localized and the illness would be cured. Such a scene showing the magic power of light, seemingly only possible in a movie now, would in all probability comes into reality in future.

Fluorescence based techniques, such as fluorescence imaging and photodynamic therapy, have shown great perspective in various biomedical applications. The physical basis of such techniques is the fluorescence properties of different molecules that either constitute the building blocks of living organisms or work as exogenously introduced luminescent biomarkers. If regarding the molecules embedded in tissues as microscopic lamps, they can be switched on remotely on demand by using laser radiation and then emit fluorescence light with molecule-dependent wavelength, which is a scientific word for “color”. In general, the lesion, such as a tumor region, would have different molecular compositions relative to healthy tissues, sometimes even with the presence of disease related biomolecules. In such a case, through lightening those microscopic lamps and the subsequent detection of the fluorescence light of different colors, the lesion can be in principle visualized and localized due to its color characteristic.

In fluorescence techniques, the introduction of exogenous luminescent molecules or phosphors is often necessary for better visualizing the lesion, as the endogenous molecules generally exhibit less spectroscopic characteristics rather than severe overlap of fluorescence spectra, making the distinction between the affected part and healthy tissue challenging. One merit of introducing exogenous luminescent biomarkers could also exist in following medical treatment, i.e., the biomarkers can be designed as a part of the

drug carrier, and the fluorescence light from them can be employed to control the release of drugs. As a prerequisite, the luminescent biomarkers need to be surface modified and functionalized, such as through coating with specific antibodies, so they can be targeting to the lesion. Common luminescence biomarkers include fluorescent dyes and semiconductor quantum dots.

Upconverting nanoparticles (UCNPs), composed of rare earth ions doped in an inorganic host material, are an emerging group of luminescent biomarkers with excellent spectroscopic and physico-chemical properties. Such nanolamps can be lightened by using near infrared excitation light and give out visible or near infrared emission with shorter wavelength than the excitation. Since the fluorescence light originating from the labeled biological tissues, usually termed autofluorescence, generally exhibit longer wavelengths than the excitation, the unique spectroscopic properties of upconverting nanoparticles manage to avoid the overlap of the fluorescence spectra of the biomarkers with autofluorescence. This enables autofluorescence-free optical imaging, guaranteeing very high sensitivity and contrast. In addition, researches show that UCNP-mediated fluorescence imaging possesses much higher spatial resolution than using conventional linear luminescent biomarkers such as fluorescent dyes, thanks to the nonlinear power dependence of upconverting nanoparticles. Besides as fluorescence contrast agents, UCNPs can be also incorporated in photo-responsive compounds that contain bio-functional molecules, and the induced ultraviolet or visible emission by near infrared excitation can be used to control the release of those bio-molecules.

Upconverting nanoparticles have been used in numerous pre-clinical biomedical applications, including microscopy, diffuse imaging and tomography, photodynamic therapy and photoactivation. Despite the great success, the low and excitation power density dependent luminescence quantum efficiency of UCNPs, especially at low excitation fluence rate that is typically encountered in deep biological tissues, hinder their successful applications in clinical settings. A large part of the present thesis has been devoted for characterizing the power density dependence of the quantum efficiency of UCNPs, and exploiting how to promote UCNPs' applications in deep tissues by tuning the way of delivering the excitation light.