Chapter 9
Fluorescent Nanomaterials and Its Application in Biomedical Engineering

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ABSTRACT

Currently, in the field of biomedical engineering and biological applications, the use of soft florescent nanomaterials has increased because of their excellent biocompatibility, easy biofunctionalization, and high brightness properties. This chapter summarizes the current developments of nano-sized fluorescent soft biological imaging agents. Many fluorescent soft nanoparticles like biomaterial-based NPs, vesicles, micelles, nanogels, small-molecule organic NPs, semiconducting polymer NPs, and dye-doped polymer NPs are mentioned briefly starting from the preparation methods, their structures, their optical properties, as well as their functionalization. Depending upon the nano-sized imaging agents' functional as well as optical properties, their uses are briefly described in relation to Vivo imaging, cellular process imaging, and in vitro imaging by using nonspecific and specific targeting.

INTRODUCTION

Nanotechnology is becoming popular in the present time. It is being used in many fields. It has become a part of our life. It is being used in various fields like nanomedicines, biomaterials, consumer products, and nanoelectronics. It involves interdisciplinary fields like mechanical engineering, electrical engineering, chemical engineering, material science, physics, biology, and chemistry. In biomedical domain, nanomaterials find various applications because of: good biocompatibility, highly loadable surface, optical, chemical, and physical properties, and their small size (Wilczewska et al., 2012). Because nanomaterials

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match sizes with various biomolecules like viruses (size variety of 1 to 100 nm), proteins, glucose, oligonucleotides, antibodies, DNA, and numerous in vivo and in vitro reports connecting biomaterials and nanomaterials are presented (Narayan., 2017). In various biomedical bids, the main use the nano-materials are in cells and tissues bio-imaging, it has held the huge interest on various researchers worldwide. This technology has now turn out to be an important tool for exploring many biological methods happening at the subcellular and cellular stages and achieving status in both clinical diagnostics and essential research. Although myriad inorganic and organic imaging probes are now accessible, nanomaterials applications as an imaging probe are now multiplying. Nanomaterials application in the bioimaging field covers point of care (POC) testing to in-depth imaging of tissues (Syedmoradi et al., 2017). In the medical field, there are many imaging modalities for accessing images of most tissues and cells. Among them includes (LA-ICP-MS) laser ablation-inductively coupled plasma-mass spectroscopy, electrochemical imaging, CT imaging, resonance imaging (MRI), radio imaging, and many more. Mentioned few methods above are destructive, need considerable sample preparation, and hold limited resolution. Because of this factors, the applications are limited for subcellular and cellular structures imaging inside the human body. This has flagged the technique for the progress of imaging probes that will have great determination, and can deliver pictures in a noninvasive way, and gives images of multinodal for gaining in-depth data. Through the expansion of novel functional biomaterials, nanomaterials bioimaging interests considerable attention in biomedical research because of the high-resolution properties, rich in contrast, sensitivity, and versatility available in this technology. This also integrates orthodox imaging techniques with a new advanced probe to record events at the cellular level having high clarity and contrast. Previously, the resolution of optical imaging was only in a limited range which is ~200 nm. With the improvement of imaging methods using fluorescence techniques, like stimulated emission depletion (STED) microscopy and photo-activated localization microscopy (PALM), the resolution is improved (Betzig et al., 2006, Willig et al., 2006). Though, a few limitations are still there for studying animal models which need in-depth imaging and high resolution. This crackdown can be limited by utilizing newly developed fluorescent nanomaterials imaging probes. Nanomaterials bioimaging mainly accepts the three main methods – (a) for making tissues and cells fluorescent, injection of fluorescent nanomaterials is done on tissues and cells; (b) targeted bioimaging; and (c) employing sensors nanomaterials for sensing the cellular biochemical types that are non-fluorescent inherently. For bioimaging of targeted tissues or cells, the precise target location is imaged by fluorescent nanomaterials. For those cases, the functional groups can be ligands, receptors, oligomers, and many more for identifying a specific location. Figure 1 shows the application of fluorescent nanomaterial in biomedical engineering area. Imaging agents of nanosizes are categorized into two types depending upon their biological environment behavior and chemical nature. They are soft nanomaterials (e.g., micelles, nanogels, polymeric NPs) and hard nanomaterials (e.g. metal nanoclusters [Sharma et al., 2011, Yu et al., 2008], carbon NPs [Liu et al., 2013, Li et al., 2013], lanthanide-doped NPs and quantum dots, dye-doped silica).

Hard nanomaterials are developed using inorganic components, especially under strict environments, by various methods. Though they are extensively used in fluorescent imaging for in vitro by surface alteration, the potential bioincompatibility and inorganic nature obstruct their real-world uses for imaging in vivo imaging (Swierczewska et al., 2011, Tantra et al., 2011, Cho et al., 2010). Presently, only one nano-sized hard imaging agent are accepted by the Drug Administration (FDA) and U.S. Food for clinical trial phase I (Cheng et al., 2013). Moreover, the fabrication of soft optical nano-sized imaging agents under mild conditions and less toxic organic molecules is done. Additionally, numerous FDA-accepted biocompatible molecules are accessible for the expansion of nano-sized imaging products, like

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