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Design and development of fluorescent nanostructures for bioimaging

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ABSTRACT

Because fluorescence-based techniques are inherently sensitive, selective, convenient, diverse, non-destructive, potentially real time and *in situ*, they have been widely used in biological imaging. Especially those, with specific fluorescent nanostructures (FNSs) as detecting media in bioimaging, have already been intensively studied for more than a decade because of the convenient transduction of optical signal, high sensitivity and rapid response of FNSs. In this review, we summarize the major strategies to design FNSs with specific structures for biological imaging. First, recent advances are briefly introduced. Then, the specific design of FNSs and their applications are reviewed, in which their fluorescence mechanism, strategies in designing and development, preparation methods, and some representative applications in bioimaging are described. Finally, future perspectives and ongoing issues of FNSs and their applications in bioimaging are discussed. Although many FNSs have been synthesized and applied biologically, many studies still should be done before they can be widely employed as fluorescent probes in clinical tests. With further advances in design and synthesis of high quality multifunctional FNSs, the widespread application of FNSs may be expected not only in advanced bioimaging, but also in ultra-sensitive molecular diagnosis, novel light-emitting nanodevices and intracellular drug delivery.

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Nomenclature

AAc	acrylic acid
ACQ	aggregation-caused quenching
AS-ODN	antisense oligonucleotide
ATRP	atom transfer radical polymerization
BODIPY	boron-dipyrromethene
BRET	bioluminescent resonance energy transfer
COPV	1,4-dimethoxy-2,5-di [4′-(cyano)styryl]benzene
CQD	carbon quantum dot
DMAEMA	2-dimethylamino ethyl methacrylate
DSA	9,10-distyrylanthrancene
DSB	1,4-distyrylbenzene
ECM	extracellular matrix
FA	folic acid
FCNP	fluorescent capsid nanoparticle
FNS	fluorescent nanostructure
FRET	fluorescence resonance energy transfer
FQY	fluorescence quantum yield
GMA	glycidyl methacrylate
GQD	graphene quantum dot
HBC	hexa-peri-hexabenzocoronene
HCP	hyperbranched conjugated polymer
HEMA	2-hydroxyethyl methacrylate
LBL	layer-by-layer
LRP	living radical polymerization
MEF	mouse embryonic fibroblast
MMA	methyl methacrylate
MNP	magnetic nanoparticle
NC	nanocluster
NIPAM	*N*-isopropylacrylamide
NIR	near-infrared
NMRP	nitroxide mediated radical polymerization
NP	nanoparticle
NVK	*N*-vinylcarbazole
PAMAM	poly(amidoamine)
PBS	phosphate buffered solution
PCPE	phosphorescent conjugated polyelectrolyte
PDI	perylenediimide
PEBBLE	probe encapsulated by biologically localized embedding
PEGMA	poly(ethylene glycol)methacrylate
PGD	polyglycerol dendrimer
PS	polystyrene
QD	quantum dot
RAFT	reversible addition-fragmentation chain transfer
RE	rare earth
RhB	rhodamine-B
SiNP	silicon nanoparticle
SWNT	single walled carbon nanotube
TPA	triphenylamine
TPE	tetraphenylethene
TPF	two-photon fluorescence
TTA	triplet–triplet annihilation
UCNP	upconversion nanoparticle
UV	ultraviolet
VBC	4-vinylbenzyl chloride

1. Introduction

Biological imaging (bioimaging) has become a powerful tool in biological research today because it offers an unique approach to visualize the morphological details of cells [1]. To date, fluorescence-based techniques have been greatly encouraged in bioimaging due to their inherent superiorities, such as high sensitivity, high selectivity, convenience, diversity and non-destructive character [2]. Typically, fluorescent probes are exploited to label the target with specific chemical structures and thus to generate fluorescent signals during the fluorescence-based bioimaging. Since nanostructure-based detection platforms can provide many advantages over traditional approaches in terms of sensitivity, signal stability and multiplexing capability, a growing interest has been shown recently in the design of different fluorescent nanostructures (FNSs) as fluorescent probes in bioimaging [3–6]. Currently, the most studied FNSs in bioimaging include fluorescent proteins, organic dyes, metal complexes, semiconductor nanocrystals, and upconversion nanophosphors [7–10]. In order to obtain a better fluorescent probe, further works on FNSs with recommended chemical and optical properties have also been reported. For example, surface modification of FNSs has been done with bright fluorescence, high photostability, large Stokes shift and flexible processability in order to be further conjugated with biomolecules and/or fluorophores [6].