Progress in Polymer Science 78 (2018) 56–91

Contents lists available at ScienceDirect

Progress in Polymer Science

journal homepage: www.elsevier.com/locate/ppolysci

Versatile types of hydroxyl-rich polycationic systems via *O*-heterocyclic ring-opening reactions: From strategic design to nucleic acid delivery applications

Fu-Jian Xu[a,b,c,*]

[a] Beijing Advanced Innovation Center for Soft Matter Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China
[b] Key Laboratory of Carbon Fiber and Functional Polymers (Beijing University of Chemical Technology), Ministry of Education, Beijing 100029, China
[c] Beijing Laboratory of Biomedical Materials, Beijing University of Chemical Technology, Beijing 100029, China

ARTICLE INFO

Article history:
Received 12 June 2017
Received in revised form 4 September 2017
Accepted 15 September 2017
Available online 20 September 2017

Keywords:
Nucleic acid
Delivery vector
Ring-opening
O-Heterocyclic
Amine

ABSTRACT

Safe and effective vectors play an important role in nucleic acid delivery processes. Ring-opening reactions are quite often used to produce biomaterials with various functions and properties. Instead of surface-conjugated hydrophilic polymers such as polyethylene glycol, uniformly-distributed hydroxyl groups within one polycation could improve biocompatibility and benefit nucleic acid delivery performances. Hydroxyl groups with uniform distribution are readily produced by ring-opening of *O*-heterocyclic units. *O*-Heterocyclic units include cyclic ester (epoxide), carbonate and *lactones*. Hydroxyl-rich polycationic systems are prepared predominately with aminated poly(glycidyl methacrylate) (PGMA). PGMA is the most common epoxy polymer and can be post-modified readily via epoxide ring-opening reactions by different amine species. Hydroxyl-rich polycationic systems are also reported by ring-opening polymerization between various epoxy and amine units. In addition, post hydroxylation of polycations via different *O*-heterocyclic ring-opening reactions could give rise to various hydroxyl-rich polycationic systems. More recently, versatile types of hydroxyl-rich polycationic systems with special molecular and topological structures, such as linear, star-shaped, comb-shaped, supramolecular, branched, hierarchical, and hetero-nanostructured carriers, are well studied. This review summarizes recent research activities in hydroxyl-rich polycationic systems. Their different design strategies via *O*-heterocyclic ring-opening reactions and unique nucleic acid delivery applications are described in detail. The research activities indicate that hydroxyl-rich polycationic systems become versatile and powerful candidates for the development of advanced multifunctional delivery systems of nucleic acids.

Contents

* Corresponding author at: Beijing Advanced Innovation Center for Soft Matter Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China.
E-mail address: xufj@mail.buct.edu.cn

https://doi.org/10.1016/j.progpolymsci.2017.09.003

Nomenclature

ABO	Amino-1-butanol
Ad	Adamantane
AEPP	*N*-(Aminoethyl)piperazine
AIE	Aggregation-induced emission
APBA	Aminophenylboronic acid
APO	Amino-2-propanol
APP	*N*-(3-Aminopropyl)-2-pyrrolidinone
APTES	3-Aminopropyl-triethoxysilane
ATRP	Atom transfer radical polymerization
Au	Gold
BD	1,4-Butanediamine
BIBA	α-Bromoisobutyric acid
BIBB	2-Bromoisobutyryl bromide
BIP-OH	2,6-Bis(1-methylbenzimidazolyl)-4-hydroxypyridine
BMA	*N*-Butylmethylamine
BSA	Bovine serum albumin
CA	Cystamine
CD	Cyclodextrin
CD/5-FC	Cytosine deaminase/5-fluorocytosine
CEST	Chemical exchange saturation transfer
CHO	Cholesterol
CL	ε-Caprolactone
CNC	Cellulose nanocrystal
CPT	10-Hydroxyl camptothecin
CT	Computed tomography
1D	One-dimensional
DEA	Diethylamine
DED	*N*,*N*-Dimethylethylenediamine
DET	Diethylenetriamine
DPA	Dipropylamine
DTPA	Diethylenetriaminepentacetate acid
EA	Ethanolamine
ED	1,2-Ethanediamine
EHDO	5-Ethyl-5-(hydroxymethyl)-1,3-dioxan- 2-oxo
EP	Epichlorohydrin
ESCC	Esophageal squamous cell carcinoma
FA	Folic acid
FM	Functional molecules
GSH	Glutathione
II	Iohexol intermediate
LA	α-Lipoic acid
LCPA	Linear cyclen-based polyamine
MEA	Methylethylamine
MRI	Magnetic resonance imaging
MPA	*N*-Methylpropylamine
NIR	Near-infrared
NR	Nanorod
QD	Quantum dot
PA	Propylamine
PAMAM	Polyamidoamine
PAI	Photoacoustic imaging
PBA	Phenylboronic acid
PBI-OH	*N*,*N*-Bis(2-[2-hydroxyethoxy]ethyl)perylene-3,4,9,10-tetra carboxylic acid bisimide
Pc	Phthalocyanine
PDM	Poly((2-dimethyl amino)ethyl methacrylate)
pDNA	Plasmid DNA
PDT	Photodynamic therapy
PEH	Pentaethylenehexamine
PEG	Polyethylene glycol
PEI	Polyethylenimine
PER	Pentaerythritol
PGEA	EA-functionalized PGMA
PGED	ED-functionalized PGMA
PGMA	Poly(glycidyl methacrylate)
PI	Phosphatidylinositol
POEAA	Poly(ortho ester amino alcohol)
PP	Piperazine
PPEGEEMA	Poly(poly(ethylene glycol)ethyl ether methacrylate)
PTT	Photothermal therapy
RE	Rare-earth
SAR	Structure-activity relationship
SHNP	Starlike hollow silica nanoparticle
siRNA	Short interfering RNA
t-Boc	*t*-Butoxycarbonyl
TACN	1,4,7-Triazacyclononane
TAE	Tri(β-aminoethyl)amine)
TAPc-Zn	Zinc(II) tetraaminophthalocyanine
TEP	Tetraethylenepentamine
TET	Triethylenetetramine
TGIC	1,3,5-Triglycidyl isocyanurate
TMC	Trimethylene carbonate
TMED	*N*,*N*,*N*′-Trimethylethylenediamine
TPE-OH	Hydroxyl-containing tetraphenylethene
TRE	Tris(2-aminoethyl)amine
UCL	Up-conversion luminescence
VE	Vinethene