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Sol–gel based materials for biomedical applications

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Abbreviations: AAM, anodic alumina membrane; AP, 3-aminopropyl; ASO, antisense oligonucleotides; BCP, biphasic calcium phosphate; BG, bioactive glass; BMSC, bone marrow mesenchymal stem cell; cAMP, cyclic adenosine monophosphate; CaP, calcium phosphate; CHO, Chinese hamster ovary cells; CNT, carbon nanotubes; CTAB, cetyl trimethylammonium bromide; CT, computer tomography; DDS, drug delivery system; DMHA, N,N-dimethylhexadecylamine; DNA, deoxyribonucleic acid; DOX, doxorubicin; ECM, extracellular matrix; EDC, 1-ethyl-3-(3-dimethyl-aminopropyl) carbodiimide; F127, Pluronic® F-127; FAP, N-folate-3-aminopropyl; FITC, fluorescein isothiocyanate; GP, guanidinopropyl; GEGP, 3-[N-(2-guanidinoethyl)guanidine] propyl; GFP, green fluorescent protein; HA, hydroxyapatite; HCA, carbonated hydroxyapatite; INDO, intermediate neglect of differential overlap; MCM, mobile composition of matter; MBG, mesoporous bioactive glass; MNP, magnetic nanoparticle; MRI, magnetic resonance imaging; MSC, mesenchymal stem cell; MSN, mesoporous silica nanoparticle; MTES, methyltriethoxysilane; MTMS, trimethoxymethylsilane; NC, network connectivity; NHS, N-hydroxysuccinimide; NIR, near infrared; NLR, long rod nanoparticles; NMR, nuclear magnetic resonance; NP, nanoparticle; NSR, short rod nanoparticles; P123, Pluronic® P-123; PAMAM, polyamidoamine; PAA, polyacrylic acid; PCL, poly(ε-caprolactone); PDMAAm, poly-(N,N′-dimethyl acrylamide); PDMS, poyldimethylsiloxane; PEG, polyethylene glycol; PEI, polyethyleneimine; PET, position emission tomography; PLL, poly (L-lysine); PLLA, poly-L-lactic acid; PMMA, poly(methyl methacrylate); PS, polystyrene; PVA, polyvinyl alcohol; PVP, polyvinylpyrrolidone; QD, quantum dots; RBC, red blood cells; RNA, ribonucleic acid; ROS, reactive oxygen species; SBF, simulated body fluid; siRNA, small interfering RNA; SPECT, photon emission computed tomography; SPION, superparamagnetic iron oxide nanoparticles; TEA, triethanolamine; TEM, transmission electron microscopy; TEOS, tetraethoxy orthosilicate; TMB, trimethylbenzene; TMES, trimethylethoxysilane; TMOS, tetramethyl orthosilicate; TTCP, tetracalcium phosphate; TTIP, titanium tetraisopropoxide; β-TCP, β-tricalcium phosphate; 3D, three-dimensional.

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ABSTRACT

Sol–gel chemistry offers a flexible approach to obtaining a diverse range of materials. It allows differing chemistries to be achieved as well as offering the ability to produce a wide range of nano-/micro-structures. The paper commences with a generalized description of the various sol–gel methods available and how these chemistries control the bulk properties of the end products. Following this, a more detailed description of the biomedical areas where sol–gel materials have been explored and found to hold significant potential. One of the interesting fields that has been developed recently relates to hybrid materials that utilize sol–gel chemistry to achieve unusual composite properties. Another intriguing feature of sol–gels is the unusual morphologies that are achievable at the micro- and nano-scale. Subsequently the ability to control pore chemistry at a number of different length scales and geometries has proven to be a fruitful area of exploitation, that provides excellent bioactivity and attracts cellular responses as well as enables the entrapment of biologically active molecules and their controllable release for therapeutic action. The approaches of fine-tuning surface chemistry and the combination with other nanomaterials have also enabled targeting of specific cell and tissue types for drug delivery with imaging capacity.

Contents