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REVIEW ARTICLE

THE ROLE OF POLYSACCHARIDE AEROGEL IN TISSUE REGENERATION AND REPAIR

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Abstract

Aerogel-based biomaterials is an important subject in materials sciences due to their vast attention in different sectors. These materials possess unique properties that distinguish them such as low density. In the area of tissue engineering, there application has been documented in areas such as blood vessel, soft tissue, nerves, bone and cartilage.There are several steps involved in aerogel preparation. The first step involves the appropriate selection of a precursor material such as polymers, silica or carbon. Aerogels have a unique property which includes the composition of mesoporous solid colloids that possess a light weight and a porous frame work structure. Aerogels also possess unique extraordinary physicochemical properties.Tissue engineering is a broad term that encompasses on using biocompatible materials to repair and replace damaged tissues. Notwithstanding, its diverse applications over the years, tissue engineering have had persistent hurdles which include the need to develop new novel biomaterials This article seeks to review the properties of aerogel and their preparation processes. The review also documented the challenges from current studies and future prospects were also discussed.
Keywords: Aerogel, biomaterials, biomedicine, material science, porosity.

INTRODUCTION

The significant attention aerogels have gained over the years especially in the field of biomaterials cannot be over emphasized[1,2]. They have a unique property which includes the composition of mesoporous solid colloids, which possess a lightweight and a porous frame work structure[3]. A definition given by Feng *et al.*, defined an aerogel as a solid component that has a unique dispersion[4]. Aerogels are remarkable materials that possess extraordinary physicochemical properties[5]. Aerogel preparation involves several steps. They have diverse applications and ability to exist in different forms such as cylinders, spheres and monolithic shapes[6,7]. In the field of biomedicals, their application is widespread to other areas not limited to tissue engineering[8,9].Tissue engineering is a broad term that encompasses on using biocompatible materials to repair and replace damaged tissues. Notwithstanding, its diverse applications over the years, tissue engineering have had persistent hurdles over the years which include the need to develop new novel biomaterials[10-14]. With these challenges in view, the promising avenue of aerogel-based biomaterials cannot be over-emphasized[15]. Some of the several reasons associated with the use of these materials include: its biocompatibility, biodegradability and mechanical strength[16]. Scientists have been able to incorporate the aerogel-based scaffolds in three-dimensional (3D) printing, thus enhancing its flexibility.

Aerogel-based biomaterials and their unique properties

Distinctive properties associated with aerogels include high porosity, low weight and surface area[17-20]. They help to increase their widespread applications in various fields. These exceptional qualities of the biomaterials to be easily handled and implemented in the human body is related to their low density and weight[21]. Some of the techniques used in the determination of aerogels include: scanning electron microscopy (SEM), small-angle scattering (SAXS), nuclear magnetic resonance (NMR) and X-ray diffraction (XRD)[22-26].

Aerogel-based biomaterials and their preparation techniques

Several key steps are involved in aerogel preparation. The first step involves the appropriate selection of a material such as polymers, silica or carbon[27,28]. These precursor materials have their own unique properties. The sol-gel process is the first fundamental method employed in aerogel synthesis[29,30]. To enhance the strength of aerogels, there is to deploy various cross-linking strategies[31,32]. The production of nanofiber-derived aerogels (PNAs) by Qian *et al.*[33], was based on the high porosity and surface area. The effect of aging on the aerogel's microstructure has been documented. According to Kawakami *et al.*, he deployed the use of water vapor in optimizing the aging process[34]. The most prevalent methods among the afore-mentioned techniques are freeze-drying and $scCO_2$ drying[35-40]. Table 1 summarizes the drying methods on aerogel characteristics, while Table 2 depicts the various strategies for aerogel preparation. Two unique characteristics mark out the supercritical drying technique. They include avoidance of structural collapse and mesopore shrinkage[40-42].

Table 1: Different characteristics of aerogels prepared by different drying techniques.

Technique	Aerogel	Raw material(s)	Characteristics	Reference
SCD	SiO_2 and carbon aerogels	Tetra-ethoxy silane, ethanol, water	Transparency, homogeneity, pore size (80 mm or less), ultra-low density, small mean particle size	44,46
SCD	nanofibers	Ammonium sulfate, $CaCl_2$	33 nm and 23 nm pore size	47
Freeze-drying	Carbon aerogels	Formaldehyde	Density of 0.112 g/cm^3	48
UAFD	Polyimide aerogels	N-N-dimethylacetamide (DMAc)	Heightened thermal insulation and increased hydrophobicity	49

SCD: Supercritical drying); UAFD: Ultrasound assisted freeze drying.

Table 2: Applied strategies of aerogels in tissue engineering.

Aerogel	Applied strategy	Synthesis technology	Results	Reference
Photo-crosslink and methacrylate	3D printing of scaffolds	Wet chemical synthesis and self-assembly.	Supports mesenchymal osteoblast differentiation	66
Alginateaerogel	3D printing of scaffolds	3D printing	cell proliferation and migration are enhanced.	67
Nanofiber aerogel	Bone scaffolds	Freeze casting	Healing was achieved in a cranial defect of size 8 mm	68
Mixture of gelatin and chitosan aerogel	Dopamine release	Covalent grafting	Production of good mechanical properties	69
Nanofiber aerogel	Typical release strategy	Amination reactions	Formation of new bone cells	70

Classification of aerogel-based biomaterials

They are classified based on two distinct properties which include: constituent materials and chemical properties[9]. Nanomaterials is one of the materials used in biomedical application[50-54].

Organic aerogels-based biomaterials

Unique characteristics associated with organic aerogels include: light weight, flexibility and biocompatibility [55-58]. Carbon based aerogels are constructed with the help of carbon-based nanomaterials. The materials exist in form of nano diamonds (NDs)[59-62]. Another component of the aerogel production are the organic polymer materials[63-65]. Cellulose has a well-known cellulose-based hydrogel derived from it[66].

Inorganic aerogel-based biomaterials

The foundation of these biomaterials consists of inorganic materials like metal oxides[63-65]. The first synthesis of silicon aerogels was in the 19th century[58]. They are also used in industrial setting and in water purification[65].

Table 3: Current perspectives of aerogel applications.

Tissue engineering application/direction	Aerogel-based biomaterials	Other added materials	Application advantages	Reference
Bone/tissue engineering	Scaffolds of nanowire origin	Hydroxyapatite	It enhances the growth and regeneration of bone cells	76
Nerve tissue engineering	Conductive cellulose/polypyrrole composite aerogels	Dodecyl-benzenesulfonic acid	It enhances the adhesion of PC 12 cells	78
Skin tissue engineering	Jackfruit aerogel	Derivatives of zinc	It enhances the regeneration of infected skin wounds	79
Muscle tissue engineering	Polydopamine aerogel	Tannic acid	It enhances the growth of myofibroblasts	80

Hybridized aerogel-based biomaterials

Distinct properties of aerogels are influenced by the selection between organic and inorganic types. They possess notable characteristics such as bio-degradability, biocompatibility and light weight[69,70]. A significant milestone was achieved by Novak *et al*., when he prepared the first silica (SiO_2) hybridized aerogel for specific applications[71]. There are various techniques deployed in the characterization of organic-inorganic hybrid aerogels[71,72]. There are two main classes of organic-inorganic hybridized aerogels[73,74]. The choice of type I or type II hybridized aerogels depends on its application[75].

Aerogel-based strategies for tissue regeneration

Properties such as biocompatibility, hydrophilicity and non-cytotoxicity are exhibited by aerogels.

CONCLUSION

The new characteristics of aerogels make them stand out as a unique material. There is need to pay critical attention on the synthesis protocols and porosity regulation of aerogels. Inherent properties of aerogels can be further explored by researchers in areas of aerogel-based biomaterials.

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AUTHOR'S CONTRIBUTION

Ezegbe CA: writing, review, supervision, **Ezegbe AG**: writing, review, **Odo KB**: writing, review, **Onyia OC**: Review, writing, **Agu-kalu A**: writing, review. **Anikwe CC:** literature survey. **Ugorji AC:** critical review. **Uchenna CP:** literature survey. Final manuscript was checked and approved by all authors.

DATA AVAILABILITY

Upon request, the accompanying author can furnish the empirical data used to bolster the findings of the study.

CONFLICT OF INTEREST

None to declare.

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