THE APPLICATION OF DENDRITIC MATERIAL IN TEXTILE ENGINEERING

Somaye AKBARI
Department of Textile Engineering, Amirkabir University of Technology
(Polytechnic Tehran), Tehran, Iran

Abstract

During the last decade, dendritic polymers including random hyperbranched polymers, dendrigrafts, dendrons and dendrimers characterized by a highly branched structure of great regularity, a compact shape, a large number of reactive end groups, and room between the branches for taking up guest molecules have attracted considerable attention. A remarkable variety of applications for dendritic polymers has been investigated as enabling building blocks for nanotechnology. A new promising area of potential applications for dendritic polymers is the field of textiles engineering.

Therefore, this review intends to introduce a brief description of the synthesis and characteristic of dendritic polymers and new potential applications of dendritic polymers in textiles engineering. With regard to the price of dendritic polymers, the application of dendritic polymer, particularly hyperbranched polymer, will be new approach to create novel features in the field of textiles engineering.

Introduction

During these past decades, the syntheses, characterization and application of nano and bio materials have been introduced into various fields of research, especially in textile engineering [1]. Among various novel technologies, dendritic architecture have been concerned recently due to the unique properties of these materials [2 - 3]. Dendritic architecture is one of the most pervasive topologies observed in nature at dimensional length scales measured in meters (trees) to nanometers (amylopectin) [4]. Due to the unique repertoire of new properties, dendritic polymers are recognized as the fourth major class of macromolecular architecture following the linear, crosslink and branched structure [5]. Dendritic architecture consists of the four subsets that are related to degree of structural control and are listed in ascending order: namely random hyperbranched polymers, dendrigraft polymers, dendrons and dendrimers revealed in Fig. 1 [6].

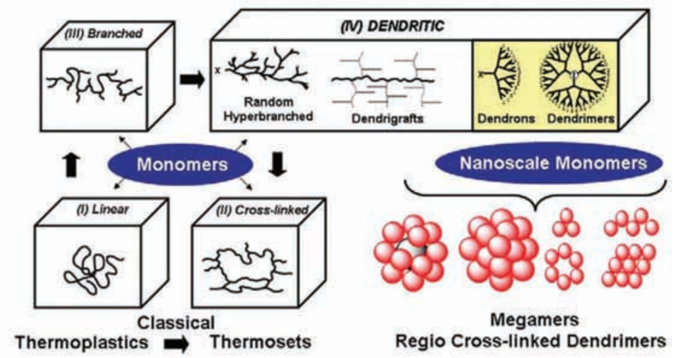

Fig. 1: Dendritic architecture consists of the four subsets: random hyperbranched polymers, dendrigraft polymers, dendrons and dendrimers *(Reprinted with permission from Ref. [6]).*

The term dendrimer refers to its characteristic appearance. It is derived from the Greek words dendron (tree branch like) and meros (part of) [7 - 8]. Synonymous terms for dendrimer include arborols and cascade molecules. However, dendrimer is currently the internationally accepted term [ ]. Generally, dendrimers consist of three basic components: a core, repeated units, and surface functional groups. The core with various multiplicities (N_c) localizes in the center of a dendrimer from which the construction of the dendrimer initiates or terminates. The repeated units or branches covalently attached to the central core are organized in a series of radially homocentric layers called "generations" (G). The branch cell also has various multiplicities abbreviated by N_b. [10]. The number of dendrimer surface groups, Z, amplifies with each subsequent generation (G) according to geometric branching laws, which are related to N_c and branch cell multiplicity N_b by the following equation 1 [11]:

$$\mathbf{Z=N_C\,N^G_b} \qquad (1)$$

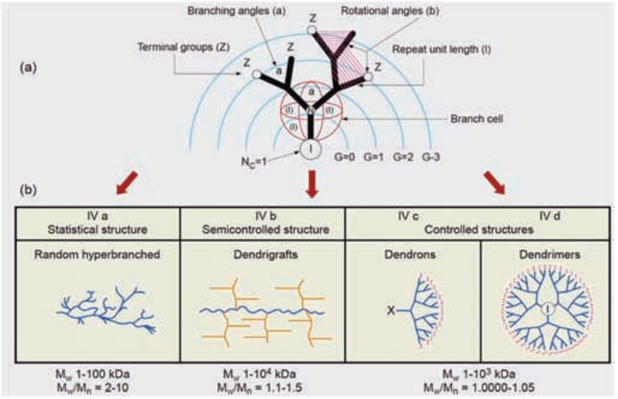

Fig. 2: All components of the dendritic structure with subclasses *(Reprinted with permission from Ref. [6]).*

Dendritic polymers may be further subdivided into four categories based on their architecture. Fig. 2 is revealed all components of the dendritic structure with subclasses [6]. As shown in Fig. 2, the dendritic polymers are open, covalent assemblies of branch cells (BCs).

The branch cells may be non-ideal with polydispersity index of Mw/Mn = 2-10 as observed for random hyperbranched polymers, or ideally organized into highly controlled core-shell-type structures as distinguished for dendrons and dendrimers (Mw/Mn = 1.0000-1.05) [1-7]. Flory was the first who apply the statistical or random hyperbranched polymers [12]. However, the first purposeful experimental confirmation of dendritic topologies did not produce random hyperbranched polymers [13]. Kim and Webster coined the popular term "hyperbranched polymers" that has been widely used to describe this type of dendritic macromolecules [14]. The other class of dendritic polymers is the dendrigraft systems, introduced simultaneously in 1991 as Comb-burst polymers by Tomalia et al. [15] and as arborescent polymers by Gauthier and Möller [16]. Dendrigraft polymers may be viewed as semi-controlled branched polymer architectures intermediate in terms of structure control between dendrimers and hyperbranched (Mw/Mn = 1.1-1.5) (Fig. 3) [17]. The multi step synthesis and slow molecular mass growth of dendrimer is often considered to be a major drawback hindering the use of these materials on a large scale. In contrast to dendrimers, dendrigrafted polymers grow faster and amplify the surface group more drastically [18].

The two most widely studied dendrimer families are the Fréchet-type polyether compositions [19] and the Tomalia-type PAMAM dendrimers [20] revealed in Fig. 3. PAMAM dendrimers constitute the first dendrimer family to be commercialized, and represent the most extensively characterized and best-understood series at this time [21]. As you can see in Fig.3, the dimension of PAMAM from 3th to 7th generation number is in the range of nano dimension. Furthermore, PAMAM dendrimer size and structure is very close to natural proteins such as insulin, cytochrome C, hemoglobin, prealbumin and hemerythrin [6].

Due to the novel characteristic of dendritic polymers, they provide a powerful tool to design hyperbranched polymers for a wide variety of applications. An area of application that, until now, has remained almost unconsidered in scientific discussions is the field of textile engineering. Therefore, this review focuses on new developments of dendritic polymers including dendrimer, dendrigraft and hyperbranched polymers in the field of textile engineering. Based on a brief description of the synthesis and characteristic of dendritic polymers, discussions of new potential textile engineering applications of dendritic polymers have been considered.

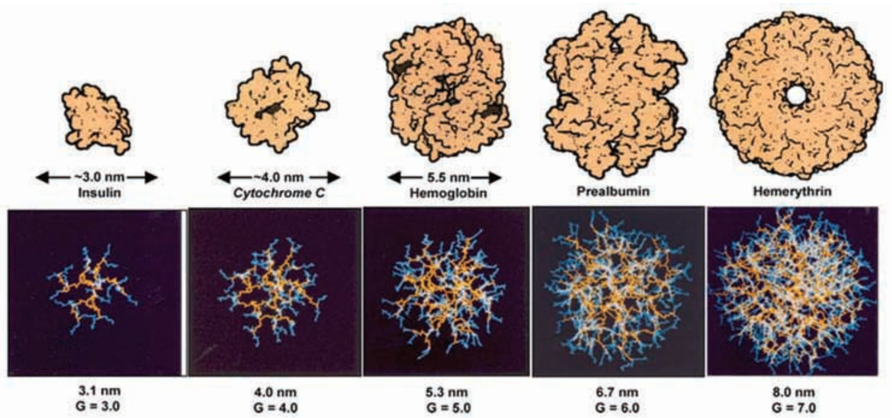

Fig. 3: The dimension of PAMAM from 3th to 7th generation number is in the range of nano dimension *(Reprinted with permission from Ref. [11]).*

Dendrimer synthesis: divergent and convergent methods

In general, synthetic methods for the preparation of branched architectures rely on two similar procedures described as divergent and convergent (Fig.4). Both procedures usually rely on mutually compatible and complementary protection and deprotection sequences [22]. In the divergent methods, dendrimer grows outwards from a multifunctional core molecule. The core molecule reacts with monomer molecules containing one reactive and two dormant groups giving the first generation; then the new periphery of the molecule is activated for reactions with more monomers. The process is repeated for several generations and a dendrimer is built layer after layer. The divergent approach is successful for the production of large quantities of dendrimers problems occur from side reactions and incomplete reactions of the end group that lead to structure defects. To prevent side reactions and to force reactions to completion large excess of reagent is required. It causes some difficulties in the purification of the final product [23]. The divergent synthetic routes first have been illustrated by Tomalia et al. [24].

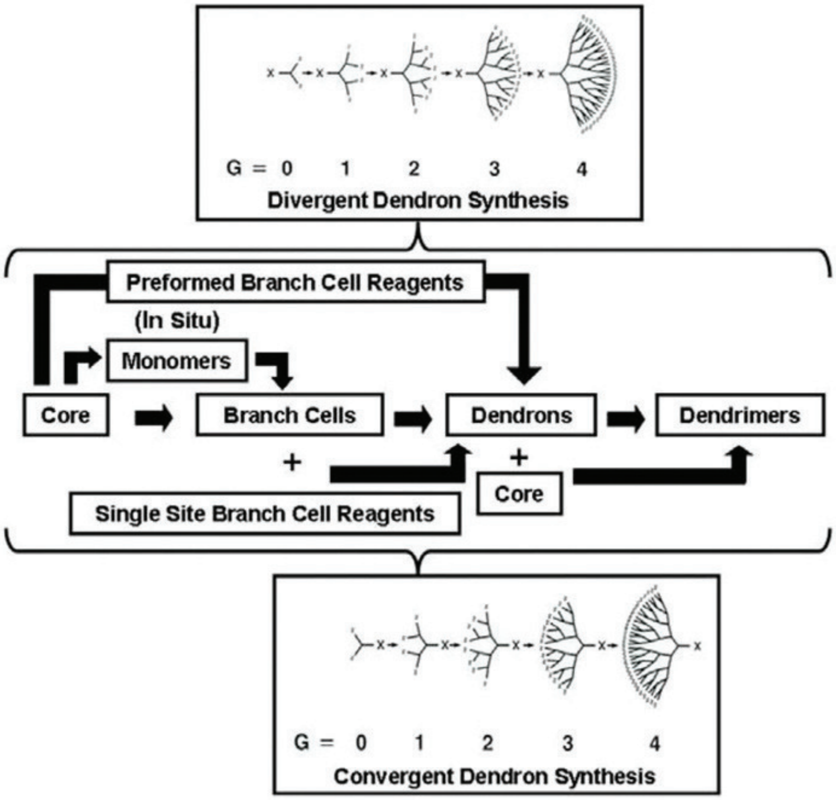

***Fig. 4: Divergent and convergent synthetic strategies for dendrimer synthesis** (Reprinted with permission from Ref. [6]).*

The convergent methods were developed as a response to the weaknesses of the divergent synthesis. In the convergent approach, the dendrimers is constructed stepwise, starting from the end groups and progressing inwards. When the growing branched polymeric arms, called dendrons, are large enough, they are attached to a multifunctional core molecule. The convergent growth method has several advantages. It is relatively easy to purify the desired product and the occurrence of defects in the final structure is minimized. It becomes possible to introduce subtle engineering into the dendritic structure by precise placement of functional groups at the periphery of the macromolecules. However, the convergent approach does not allow the formation of high generations because steric problem occur in the reactions of the dendrons and the core molecules [25]. The convergent synthetic routes first have been illustrated by Fre´chet et al. [26].

Furthermore, in contrast to the notable differences inherent in the core first (divergent) or core last (convergent) techniques, there is some similarity. The convergent protocol can be considered a "higher order" divergent method whereby "complex" monomers are attached to a central unit whether it is formally a final core or simply another self-similar monomer. However, this is where the similarity ends, as there are major differences in the outcome of using each technique. The overview of synthetic strategies for dendrimer construction annotated with discovery scientists is illustrated in Fig. 5 [6].

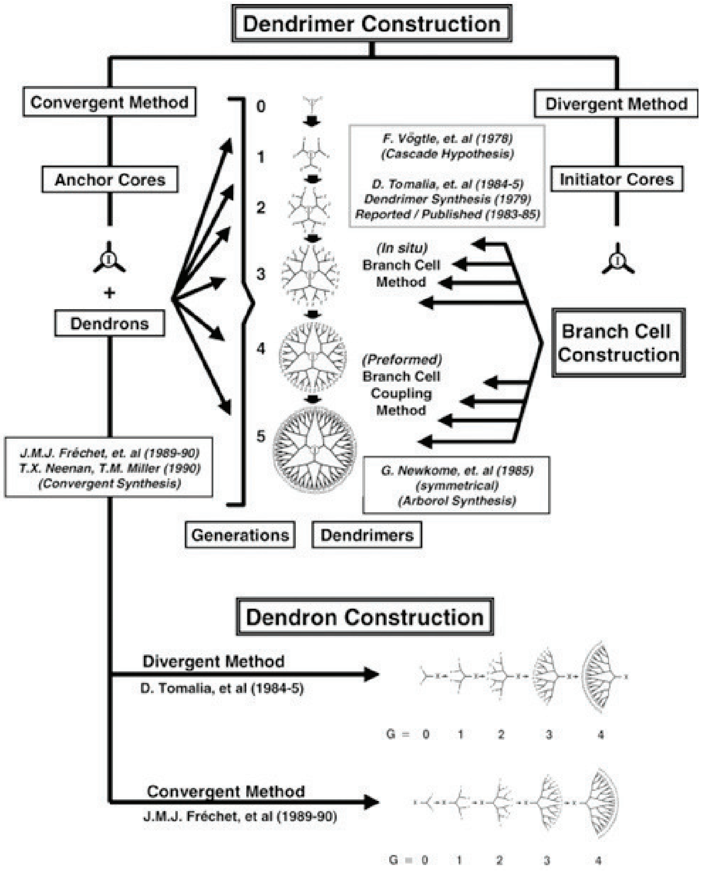

Fig. 5: Overview of synthetic strategies of dendritic polymer annotated with discovery scientists *(Reprinted with permission from Ref. [10]).*

For instance, the strategy for the first synthesized Dendrimers, polyamidoamines (PAMAMs), has been illustrated in Fig. 6 [6]. PAMAM dendrimers were synthesized by the divergent approach. Typically, ethylenediamine (N_C=4) or ammonia (N_C=3) are used as cores and allowed to undergo reiterative two-step reaction sequences involving: (a) exhaustive alkylation of primary amines by Michael addition with methyl acrylate, and (b) amidation of amplified ester groups with a large excess of ethylenediamine to produce primary amine terminal groups. Each complete reaction sequence results in a new dendrimer generation. The half generations PAMAM dendrimers (e.g. 0.5, 1.5, and 2.5) possess anionic surfaces of carboxylic groups as illustrated in Fig. 6 [6, 10].

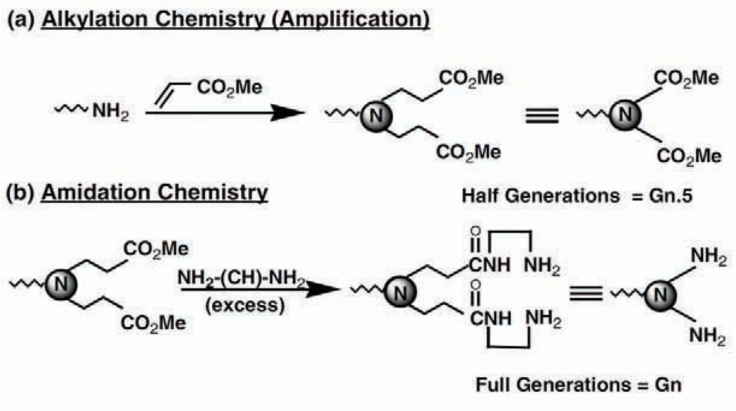

Fig. 6: The strategy for the synthesis of polyamidoamines (PAMAMs) Dendrimers *(Reprinted with permission from Ref. [6]).*

Dendrigraft synthesis:

In comparison to dendrimer synthesis, dendrigrafted structures also have been synthesized by three different strategies. The ‘grafting onto’ and ‘grafting from’ methods are both divergent techniques analogous to the core-first dendrimer syntheses. The divergent ‘grafting onto’ methods is based on successive coupling reactions of polymer chains with a functionalized substrate polymer, while divergent ‘grafting from’ methods is used cycles of polymerization initiated from functional sites located on a substrate polymer. The ‘grafting through’ method is a convergent approach more closely resembling the hyperbranched polymer syntheses involving coupling of preformed polymer chains in a one-pot reaction [15-17,27]. The first dendrigraft polymers reported in the literature, the Comb-burst and arborescent polymers, were prepared according to grafting onto schemes [17].

Dendritic characteristic

The properties of polymer materials can be well adjusted by changing the polymeric structure. Due to their highly branched and functionalized structures, globular shapes, well-defined molecular weights and sizes, monodispersity, multivalency, and relative nonpolar interior cavities [28], dendritic polymers show many intriguing physical and chemical properties, which is distinct from the other polymer structure. One of the most important characteristic is safety and efficacious of dendrimer particularly in biomedical applications. It is found that the toxicity of the dendrimer-based product was surface functional group, dose and generation-dependent in vitro as well as in vivo, whereas low generations (below 5th) were not toxic [29-30]. In the following sections, the novel characteristics of dendritic polymers are discussed.

Rheological and Mechanical properties:

The intrinsic viscosity of polymers depends greatly on the molecular architecture. In General, the intrinsic viscosity of linear polymers, that obey the Mark—Houwink—Sakurada equation, increases steadily with increasing molecular weight, whereas a maximum appears for a dendrimers at a certain dendrimer generation [31]. For hyperbranched polymers, the intrinsic viscosity also increases with increasing molecular weight but much lower than that of linear counterpart [32-33]. The dendrigraft polymers have similar trend with the dendrimers [34]. Hammond et al. [35-36] revealed that the chemistry of the end groups and its interaction with the solvent were found to be more important at low generations, whereas at higher generations, the highly branched nature of the dendritic block was the more important factor.

As a consequence of the excluded volume associated with the core, interior and surface branch cells, steric hindrance are expected to occur due to tethered connectivity to the core. The steric congestion increases by rising generation number, Nc¬ and Nb according to de Gennes prediction as 'de Gennes' dense-packed generation [10]. Ideal dendritic growth without branch defects is possible only for those generations preceding this dense-packed state. This critical dendrimer property gives rise to self-limiting dendrimer dimensions [37].

The same behavior is also observed for the density. By increasing generation numbers, a minimum is observed in the density at the certain generation. The change of density with the generation can be explained with reference to the density distribution and fluctuations inside dendrimers, in the simplest case. Lescanec and Muthukumar [38] believed the density to be the greatest at the core and to have a monotonic decrease to the edge; Indeed, de Gennes and Hervet [39] expected the minimum density to be at the core and to increase monotonically to the outer edge. Akbari et al. [40-41] also observed a minimum density for the first generation and the monotonic increase for the additional generation in the dendrigrafted structure which are consistent with de Gennes and Hervet's prediction for dendrimers.

Fig.7 illustrated the surface area/head group (Z), refractive index, density (d) and intrinsic viscosity as a function of generation for PAMAM dendrimer from 1 to 9 generations [10]. The de Gennes dense-packed occur between generations 4 and 5 which refractive index and density revealed minimum, whereas intrinsic viscosity demonstrated maximum at the mention generation [10].

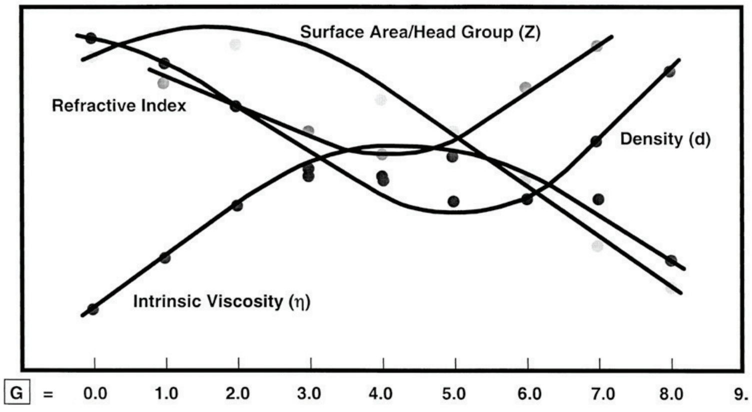

Fig. 7: Comparison of surface area/head group, refractive index, density and intrinsic viscosity as a function of generation *(Reprinted with permission from Ref. [10]).*

The very narrow polydispersity index as one of the most characteristic of dendritic structure was discussed in introduction section due to the importance of this characteristic.

Host-guest properties:

Host-guest chemistry involves the binding of a guest molecule in a receptor molecule as a host one. The design and construction of hosts that are capable of selectively binding guest molecules requires precise control over geometrical features and interacting complementarily [42]. The possibilities for encapsulating guest molecules in dendritic host as an ideal molecular containers proposed by Maciejewski in 1982 [43]. As dendritic structures possess an exterior end groups at the periphery and interior hollow branch or core, they should be able to act as a host for guest molecules. Hence, the nature of the host-guest interaction is varied by increasing generation numbers.

Poly(amidoamine) (PAMAM) dendrimers reveals the periodic properties as a function of generation (G=0-10). It demonstrates flexible scaffolding for generation beyond 4, container properties for generation between 4 to 6 and rigid surface scaffolding for generation after 7 where de Gennes dense packing is severe. These three domains have been illustrated in Fig. 8 [6]. According to Fig. 8, by increasing generation, the shape of dendrimer has been changed from flat, floppy conformations to robust spheroids. As a result, entrapment of guest molecules is difficult in earlier generation due to the low cavity, whereas the steric hindrance has limited penetration guest into the higher generation.

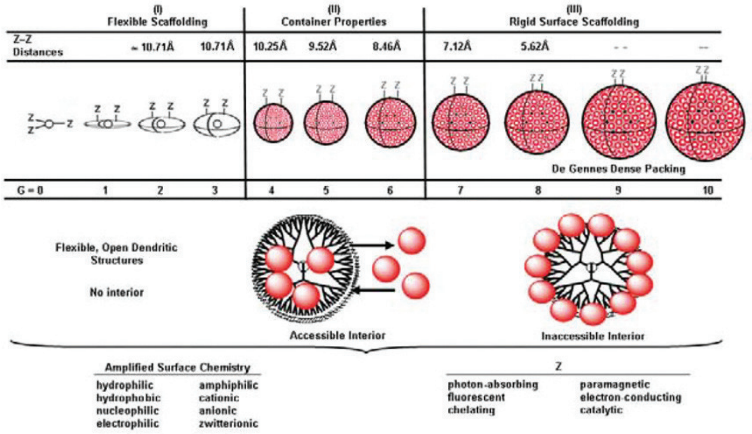

Fig. 8: Periodic properties of PAMAM dendrimers as a function of generation *(Reprinted with permission from Ref. [6]).*

On the other hand, the type of solvent, pH and ionic strength can be influence on the structure and conformation of dendrimers [44]. For instance, PAMAM dendrimers have an extended conformation at low pH resulting from repulsions between primary and tertiary positively charged amines. At neutral pH the size of the dendrimer decreases probably due to hydrogen bonding between uncharged tertiary amines and positively charged surface amines. At high pH, dendrimers contract since the global charge approaches neutrality. With decreasing solution pH, there is further increase in the size of the dendrimers [45]. Similar trend have been observed for PPI dendrimer [46-47].

The novel characteristics of dendritic polymers make them suitable to wide various applications discussed in next section.

Applications of dendritic materials

The versatile structure of dendritic structure gives to dendrimers the capability of including a wide variety of applications such as medical [48], health care, cosmetic, catalytic agent, molecular weight and size standards, chemical / biological sensors & detectors [49], textile additive, polymer and plastics additives (e.g. for lowering viscosity, increasing stiffness, incorporating dyes, compatibilisers, etc.), creation of foams (i.e. synthetic zeolites or insulating material), building blocks for nanostructured materials, consumer goods, ink/laser-printing toners [50], dyes and paints [51], industrial adhesives, manufacture of nanoscale batteries and lubricants [52], and various healthcare/medical applications [53] such as biomedical application [54], drug delivery [55], and biomolecular binding agents [56], cellular Transport, artificial cells, diagnostics and analysis [57-58], targeted delivery supermolecular assembly [59-60], catalyst [61-62], MRI contrast agents [63-64] and other aspects of dendrimer applications [65]. As mention before, dendritic polymers provide a wide variety of applications. An area of application that, until now, has remained almost unconsidered is the field of textile engineering. As a result, this review followed by a discussion of new potential textile engineering applications of dendritic polymers.

Applications in the field of textile engineering

Novel characteristic of dendritic polymers such as highly branched structures, large number of reactive end groups and room between the branches for taking up guest molecules create these fourth classes of polymer a suitable candidate for use in the textile engineering. The only limiting factor in the widespread applications is the price of these compounds, especially dendrimers. The traditional process for creating dendrimers such as PAMAM includes an amidation step that involves thermodynamically driven, lower reaction rate, chemistry, accompanied by long reaction times. These process features require high excesses of reagent and high dilutions resulting in low production capacities per reactor and thus high costs, particularly at higher generations.

In comparison with dendrimers, hyperbranched polymers represent versatile carrier molecules with a promising price/performance ratio. They are commercially available on a ton-scale at prices ≥4 euros/kg. This opens up possibilities to meet the requirements of several challenging encapsulation and controlled-release applications [66]. As a result, for large-scale industrial use an economic alternative for dendrimers has been found in the hyperbranched polymers, which share many of the dendrimers' special properties.

In the case of dendrimer, the Priostar families of dendrimers [67] involves the use of faster, kinetically driven chemistry, combined with the use of polyfunctional branch cell reagents to rapidly and precisely build dendrimer structures in a controlled way, generation by generation. This present process yields precise structures with cleaner chemistry, requires lower excesses of reagents, and lower levels of dilution, thus offering a higher capacity method that is more easily scaled to commercial dimensions, and providing new ranges of materials at lower costs. With regard to the manufactured of dendritic polymers in high volumes at costs attractive, a wide variety of uses can be considered in the textiles engineering. Fig. 9 illustrated the various applications of dendritic polymers in the field of textiles engineering discussed in this review.

Fig. 9: The various applications of dendritic polymers in the field of textiles engineering

Dye and Dyeing fabric:

The application of dendritic materials in textiles engineering have been first utilized for the dye in a variety of purpose such as structure control and probe for dendrimer, dye combined with dendrimer for capture and transfer of photon energy, extraction and encapsulated of dye by dendrimer [68]. Specially, the interaction between dyes and dendritic polymers is especially interesting [69]. Furthermore, dendrimers have found a number of applications in inkjet printing and related techniques [49] and laser applications [70].

Dendritic polymers have been used for dyeing polypropylene fiber which usually dyed in master-bach process. Froehling [71] explained that it is possible to lock guest molecules physically within the internal cavities of a dendritic host, while the versatility of reactive end groups can be tailored to attract dyes as well as other chemical additives. Furthermore, hyperbranched polymeric additives such as Boltorn H40 have been utilized for dyeing polyethylene perephthalate (PET) fiber and sheet by disperse dye [72-73]. The thermodynamic parameters of disperse dye as well as thermal behavior of PET fiber has been investigated well by Bozorgi et al. [74-76].

The salt-free dyeing on cotton has been utilized due to contribute to environmental non-pollution an undertaken to explore promising approach to reduce cost of dye process [77]. Burkinshaw [78] applied amine terminated dendrimer, for pretreatment of cotton for reactive dyeing. The results revealed that color strength of reactive dye increased with increasing amount of dendrimer applied for pretreatment of cotton fabric in the absence of both electrolyte and alkali. The similar results were studied using direct dyeing on cotton [79]. Besides salt free dyeing, the treated fabric with an amino-terminated hyperbranched polymer revealed antibacterial properties [80].

In addition, the aggregation of other dyes such as Methylene blue [81] and azo [82] were investigated in the presence of the dendritic polymers due to the large amount of functional end groups. Another approach to the use of the dendritic polymers is to improve the solubility of poorly soluble dyes.

Wastewater:

One of the most important applications of dendritic polymers would be their use as the removal of textile dyes and other additives from aqueous solutions as well as encapsulate water contaminants such as metal ions due to the interaction ability of their interior and functional end groups at the periphery of a dendritic structure. Fig. 10 demonstrated the recovering of metal ions from aqueous solutions by dendrimer-enhanced ultrafiltration [83]. The recovery of metal ion as well as dendrimer for repeated use which provides economically feasible processes was possible by decreasing the solution pH to 4.0 [84].

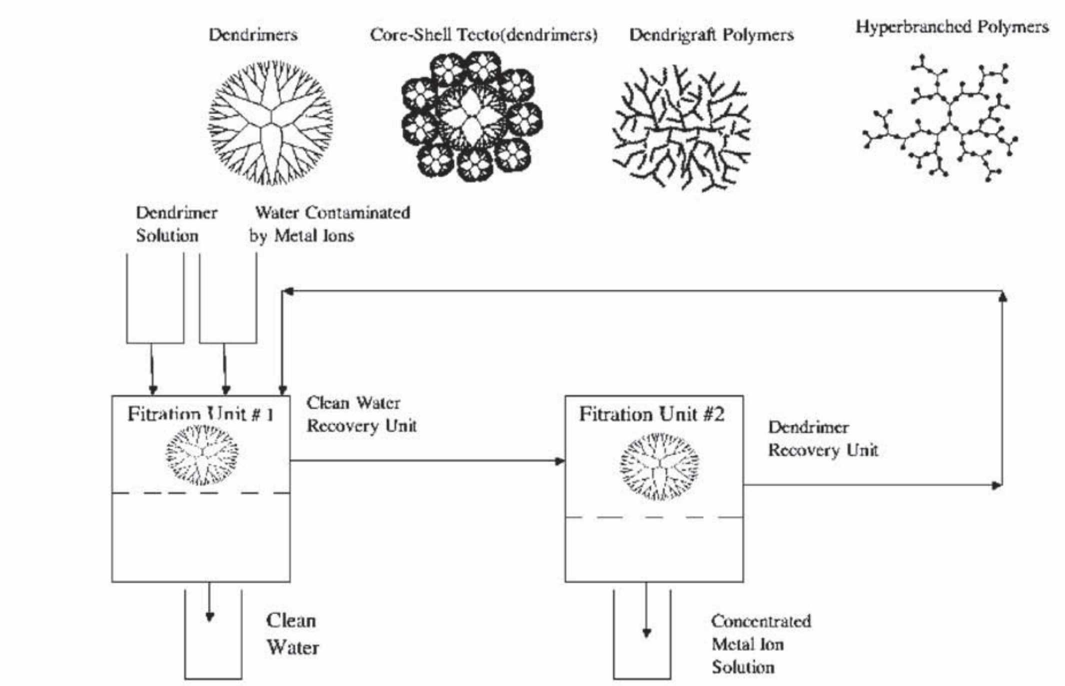

Fig. 10: Recovery of metal ions from aqueous solutions by dendrimer enhanced ultrafiltration *(Reprinted with permission from Ref. [85]).*

Dye removal from colored textile wastewater by poly(propylene imine) dendrimer was studied by Hayati et al. [85]. In addition, surface modification [86] and production of a composite nanofiltration membrane using dendritic polymers is a utilizing feature in wastewater application [87].

Drug delivery using fabric:

Besides, widespread application of various dendrimers in drug delivery or biological application, drug delivery through textiles is a novel promising feature of application of dendritic materials. Among various characteristic of dendritic properties, host-guest properties of dendritic molecules has developed significantly and now occupies a unique position within the area of supramolecular chemistry [88]. Due to the presence of functional end group at the periphery as well as the hallow interior in dendritic boxes [89], control of drug release through fibers is possible. Therefore, they exhibit great potential application especially on the nanometric scale as a nanoscale container and scaffold such as fiber [90]. These unimolecular container and scaffolding behaviors appears to be a periodic property that is specific to each dendrimer family or series. Similar cyclodextrin, dendritic polymer can be utilized for this purpose [91].

Novel finishing:

In these days, incorporation of novel finishing processes on fabric using nanotechnology has been receiving considerable attention. Among various nano and bio materials, applications of dendritic polymers have been concerned recently in textile industries due to the unique properties of these materials. The versatile structure of dendritic polymers give them to capability of including a wide variety of nonpolar or charged guest molecules into their hydrophobic pockets by hydrophobic/hydrogen-bond interactions, or on the surface by electrostatic interactions, forming different types of inclusions or ion-pairs in aqueous solutions [92]. These characteristic makes dendritic polymers suitable candidate in various finishing agent on the textiles, particularly for the carriers in host-guest systems. A variety of finishing process can be applied on textiles in the presence of dendritic polymers such as flame retardant, super hydrophobic, antistatic, super hydrophilic, perfumery, antibacterial, and water/oil repellency properties which discussed in this section.

The application of permanent fragrant worsted fabric utilizing dendritic material as one of the nano size materials was concerned by Akbari et al. [93]. It seems that fragrance can be stuck into the internal branch cells and the functional end groups of dendritic materials can be attached to the fabric. Consequently, these binding on the fabrics make almost permanent fragrant into the worsted fabric without any effect on physical properties such as breaking strength, bending length, air permeability, fabric weight and wrinkle recovery angles.

Physical properties, salt-free dyeability, antimicrobial activity, and antiultraviolet property of the treated cotton samples were tested by Zhang et al. [94]. Their investigation revealed that the treated cotton fibers by dendritic polymer had no effect on the mechanical properties. Besides, the application of amino-terminated hyperbranched polymer can enhance the substantivity of the cotton fabric, reduce the electrolyte dosage, and potentially lead to salt-free dyeing as well as improvement of the thermal stability and the moisture regain. Furthermore, the treated cotton fabric can be dyed with acid dyes effectively, reduced UV transmission and increased UPF.

Furthermore, it seems that the antimicrobial property of textile fabric treated with amine terminated hyper branched polymer as well as dendrimer consider more attention due to the presence of huge cationic end groups [95-96]. For instance, the excellent antimicrobial property of cotton cellulose fabric grafted with poly(propylene imine) dendrimer have been recently studied [97-98]. Ghosh etal. [99] revealed that modified dendrimers with ammonium functionalities and silver-dendrimers complexes exhibited antibacterial efficacy against S. aureus when applied onto the Nylon/Cotton blend fabric.

In addition, the effects of water repellency of cotton/polyester blended fabric on the physical properties as well as color assessment of blended fabric were investigated in the presence of fluorocarbon , nanoparticle and dendrimer by Colleoni et al. [100]. It has been showed the dyestuffs do not interact with finishing products after modification of the surface roughness. Furthermore, mechanical characteristics of the fabric are not significantly altered by finishing treatments.

Surface modification:

The use of dendritic polymers as surface modification on the fiber, film and fabric is fairly unexplored and their application is still to be optimized; in this section, their influence on novel characteristic is worthy of investigation, particulary the dendrigrat formation on the surface. For instance, chemical modification of chitosan with cationic hyperbranched dendritic polyamidoamine on cotton fabric has been investigated to improve dye uptake as well as antimicrobial activity [101]. Surface modifications of cotton fiber for apparel use also have been considered by dendrimer [102]. Acrylic copolymers film has been modified via dendrigrafted with citric acid illustrated in Fig. 11 [103]. This modification has been improved the characteristics of the fibers such as swelling/de-swelling in basic and acidic media as pH actuators, nanocarbon fiber precursors, or as active particles for loading with guest molecules [104].

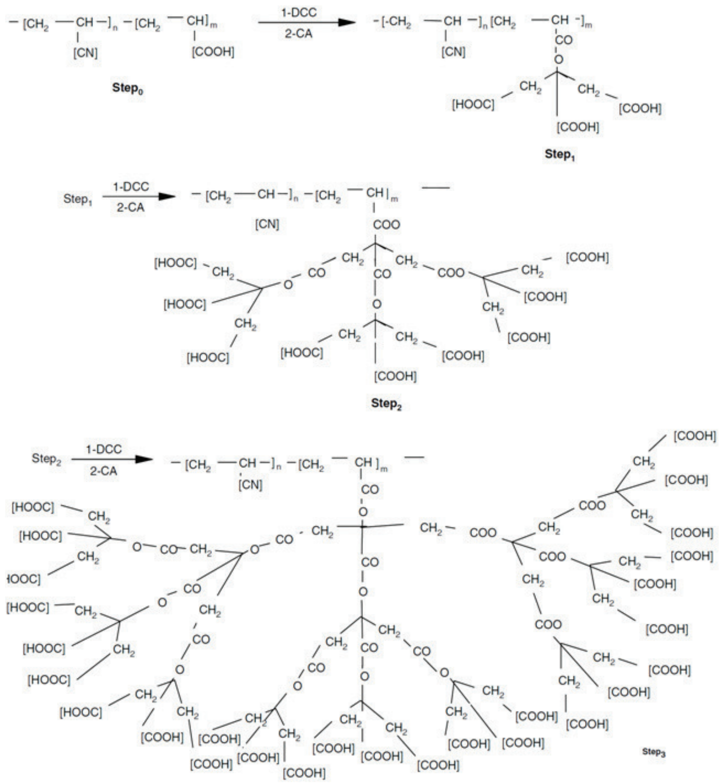

Fig. 11: Theoretical preparation routes of citric acid dendrigraft from zero to four generation with 100% conversion as surface modification of acrylic copolymer. *(Reprinted with permission from Ref. [103]).*

Conclusion

During the 21st century, dendritic polymers reveal a key role as enabling building blocks for nanotechnology. Dendritic polymers are recognized as the fourth major class of macromolecular architecture consisting of four subclasses including random hyperbranched polymers, dendrigrafts, dendrons and dendrimers. They characterized by a highly branched structure of great regularity, a compact shape, a large number of reactive end groups, and room between the branches for taking up guest molecules have attracted considerable attention. Therefore, they exhibit great potential application especially on the nanometric scale as a nanoscale container and scaffold. These properties are determined by the size, shape, and multiplicity of the construction components that are used for the core, interior, and surface of the dendrimer. As a result, a remarkable variety of applications for dendritic polymers has been investigated in the field of textiles engineering.

This review covers the synthesis, characteristic and new potential applications of dendritic polymers in textiles engineering in the variety of applications including wastewater, permanent fragrant fabric, water repellency, improvement of dye ability, dyeing PP fabric, drug delivery using fabric, novel finishing, surface modification, antibacterial properties. With regard to the price of dendritic polymers due to complex multistep synthesis of dendrimers, the application of dendritic polymer, particularly hyperbranched polymer, will be new approach to create novel features in the field of textiles engineering.

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