Chapter 13
Kapok Fiber: Applications

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Contents

Abstract Kapok fiber is obtained from the seed hairs of kapok trees (*Ceiba pentandra*) and belongs to a natural cellulosic fiber. Kapok fiber is consisted of abundant hollow microtubes with the unique structure of void content as high as 80–90 %. Conventionally, kapok fiber is used as the stuffing for pillows, bedding, and some soft toys. Owing to excellent buoyancy and air-filled lumen, kapok fiber is also utilized as the buoyant material (such as life preservers) and insulation materials against sound and heat. Due to better warm retention property, kapok fiber can blend with other fibers to achieve the required apparel textiles. Kapok fiber contains wax layer on its surface, which affords this fiber to show excellent hydrophobic–oleophilic characteristics, and accordingly, this fiber has received much attention in

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recent years as the oil-absorbing material. Featured with natural microtubes structure, kapok fiber can also be used as a desirable template material or supported candidate such as for catalyst carriers. This chapter provides a summary of recent applications of kapok fiber, with special attention to some fields being developed.

Keywords Kapok fiber • Application • Oil-absorbing material

13.1 Introduction

Kapok is a silky fiber that encloses the seeds of kapok trees (*Ceiba pentandra*) and the color is yellowish or light-brown with a silk-like luster. In contrast to cotton fiber, the kapok fiber is single-celled plant hairs. Owing to its hollow air-filled lumen and high void content, kapok fiber is conventionally used as stuffing for insulation against sound and heat, and for bedding, pillows, life preservers, and other water-safety equipments because of its excellent buoyancy. Due to the unique features, kapok fiber-based materials have opened the possibilities for various new application fields. Figure 13.1 shows the representative relationship between structure, properties, and applications for kapok fiber.

13.2 Applications of Kapok Fiber

13.2.1 Apparel Textiles

In the early years, kapok fiber is considered unfit for textile fabrics. However, the weavability can be enhanced by blending with other fibers. Generally, the addition of kapok fiber into the fabrics or wadding will improve the warm retention though

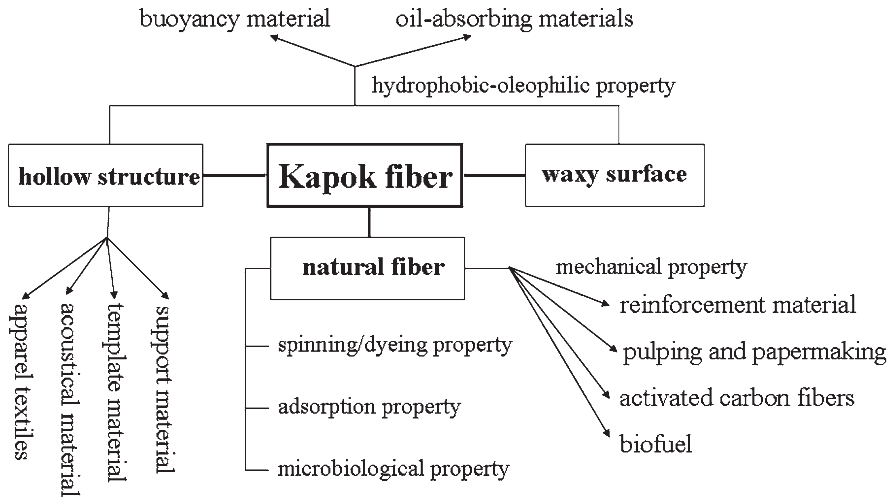

Fig. 13.1 Representative relationship between structure, properties, and applications for kapok fiber

the compression elasticity may be affected (Cui et al. 2010; Wei et al. 2008). The kapok/cotton fabric had met the basic requirements on apparel textiles, showing better performance than cotton fabric in air permeability, warmth retention, and durability, especially the warmth retention of plain woven kapok/cotton fabric. However, its wear resistance and crease recovery were slightly poorer than those of cotton fabric. Therefore, it is suggested for kapok/cotton fabric that loose texture, for example satin, should be chosen for summer, and plain weave should be selected for winter, by which cavities of kapok fibers can be fully utilized for realizing reasonable air permeability and warmth retention (Han et al. 2010). In addition, the kapok blended fabrics are observed with better hygroscopicity and moisture guide properties (Lou 2011). Comparative analysis showed that addition of kapok fibers into viscose/polyester blend fabric improved the warm retention, anti-ultraviolet radiation, and crease recovery. And also, the fabric was more likely to accumulate charge but with fast charge dissipation (Hong et al. 2012).

13.2.2 Buoyancy Material

Owing to large hollow structure and waxy surface, kapok fiber shows excellent hydrophobic–oleophilic characteristics. As the water drops are deposited onto the surface of kapok fiber, the intrinsic hydrophobic nature of fiber will cause a repelling force which will prevent the water drops from spreading onto the surface of kapok fiber (Fig. 13.2). Additionally, more wrinkles with the height of several nanometers are decorated on the cylindrical microtube of kapok fiber, and this micro-nano-binary structure will also produce positive contributions for its hydrophobic–oleophilic characteristic. Combining hydrophobic–oleophilic characteristic with lightest quality, kapok fiber aggregates ideally are applied as the life-saving supplies.

From previous studies, the optimal density of kapok fiber aggregates with 5 cm height is 0.015 g/cm^3. Accordingly to the common international standard, this 5 cm height corresponds to 0.5 kPa hydraulic pressure for evaluating buoyancy materials. The kapok aggregates with this density show excellent resistance to the outer hydraulic pressure and can keep a constant capacity up to 5 kPa. Compared with some artificial buoyancy materials, the optimal density of kapok fiber aggregates is at least 20 times lower. For example, this density is 0.3 g/cm^3 for life jacket foam and 0.37–0.42 g/cm^3 for poly (vinyl chloride) (PVC), polyurethane (PU), polystyrene (PS), or PE foam. The resulted high buoyancy multiple implies that kapok fiber aggregates show an excellent buoyancy performance and are expected to be an ideal buoyancy material (Zhang et al. 2013). However, the buoyancy would decline after the material is being used or stored for a long time, as it would be compressed due to fiber migration. Consolidating kapok fiber into webs with low-melting point fiber can improve the buoyancy behavior of the kapok fiber assembly, obtain a compression resistance even better than the kapok/three-dimensional crimped hollow polyester fiber assembly and provide higher buoyancy factor (Xiao et al. 2005). To improve the uneven structure, a processing way of combined action of air carding and mechanical blending can be employed to replace the hand padding (Shi et al. 2009).

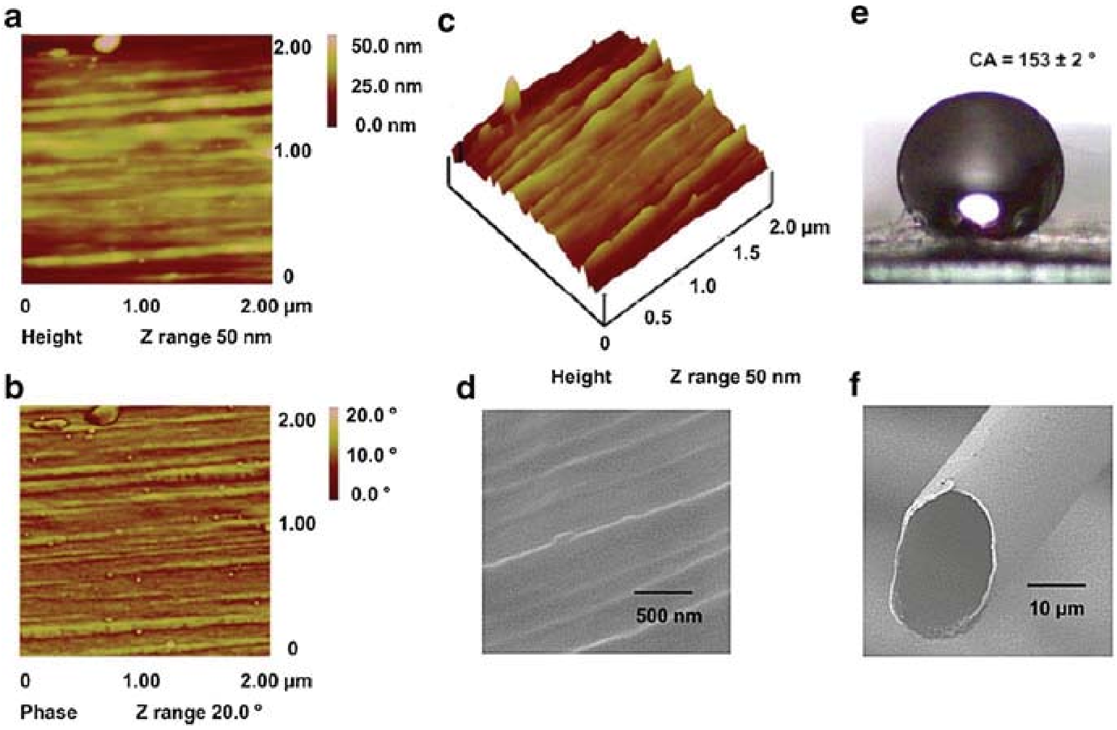

Fig. 13.2 (**a–d**) are the AFM height image, phase image, the according three-dimensional view, and the SEM image, of the outer surface of a kapok fiber, respectively. Nano-scaled wrinkle on the surface can be clearly seen. (**e**) CA of a water droplet on kapok fiber films is measured to be 153 ± 2. (**f**) SEM image of a natural kapok fiber with micro-scaled diameter (Zhang et al. 2013) Copyright 2013, reproduced with permission from Elsevier

13.2.3 Acoustical Material

Noise pollution is the disturbing or excessive noise that may bring heavy damage and great stress on the activity and balance of human or animal life, such as hearing impairment, disturbance of sleep, psychophysiological and mental health, and so on. Therefore, it is necessary and important to develop economical and environment-friendly acoustical materials to control the noise pollution. Traditional acoustical materials generally include fibers, foams, perforated panels, membranes, and their composites.

Different from other fibers, kapok fiber has large lumen and thin cell walls. The special structure of kapok fiber is expected to be beneficial for the sound absorption since it increases the chance of friction between sound waves and fibers. Some studies reveal that the kapok fiber has excellent acoustical damping performance and the sound absorption coefficients of kapok fibrous assemblies are significantly affected by the bulk density, thickness, and arrangement of kapok fibers but less dependent on the fiber length. Compared with assemblies of commercial glass wool and degreasing cotton fibers, the kapok fiber assemblies with the same thickness but much smaller bulk density may have the similar sound absorption coefficients (Xiang et al. 2013). The kapok fiber can also be combined with other fibers, such as polypropylene fiber to obtain a composite with sound absorptive property.

The values of sound absorption coefficient and noise reduction coefficient obtained indicate that the kapok fiber composites possess very good sound absorption behavior in the frequency range 250–2,000 Hz (Veerakumar and Selvakumar 2012). Furthermore, kapok fiber possesses some ecological characteristics such as environment-friendly, biodegradable, renewable, safe fiber handling, and low energy consumption. Combined with excellent chemical stability, it can be concluded that kapok fiber is a promising light and environment-friendly sound absorption material for potential applications in noise reduction field.

13.2.4 Oil-Absorbing Materials

Over the production, storage, and transportation of oils, there are always possible risks of oil spillage. Oil spills often result in immediate and long-term environmental damage, especially for marine areas since the spilled oils can form a thin coating over the hundreds of nautical miles. This is a major problem on the coastal environment and marine resources, and has created public and government awareness and concern. To minimize the possible environmental impacts in the event of oil spillage, some oil spill remediation products have been developed for the cleanup and recovery of oil spills, including but not limited to dispersants, solidifiers, demulsifiers, gelling agents, absorbents and biological agents, etc. Mostly, polypropylene fiber-based oil sorbents are used to clean up oil spills. However, this synthetic material will present serious environmental problems owing to their non-biodegradable characteristics at the end of usage.

Kapok fiber, a natural, inexpensive, hydrophobic–oleophilic agricultural product, is then considered to be a better alternative to those widely used synthetic materials. Owing to its hollow lumen and thick wax layer, kapok fiber exhibits high hydrophobic–oleophilic characteristics, and this intrinsic nature makes kapok fiber have high oil retention and reusability. Additionally, in the mixture of oil and water, the polypropylene fiber-based oil sorbents tend to sink just after 3 min, while this phenomenon cannot occur for the kapok fiber assemblies (Rengasamy et al. 2011). Compared to polypropylene, kapok fiber is relatively cheaper, and can be recovered from spent bedding, pillows, soft toys, and life preservers for reuse as the oil sorbents. Due to its eco-friendly properties, kapok fiber can be ultimately applied for biomass energy recovery and accordingly, no secondary wastes can be produced during its usage as a result its biodegradability (Lim and Huang 2007a).

Featured with lower density, higher porosity, greater specific surface area, and hydrophobic–oleophilic characteristics, kapok fiber is now receiving great attention as the filter product for deep-bed filtration in achieving oily water separation. Through the kapok-packed filter column, a series of pictures are taken to describe a typical diesel/water separation process when the oily water passed (Fig. 13.3). During the oil/water separation process, the dynamic behavior can be classified into four stages, i.e., infiltration, separation, displacement, and equilibrium. For the kapok filters, the optimum packing density was determined to be 0.07 g/cm^3, and

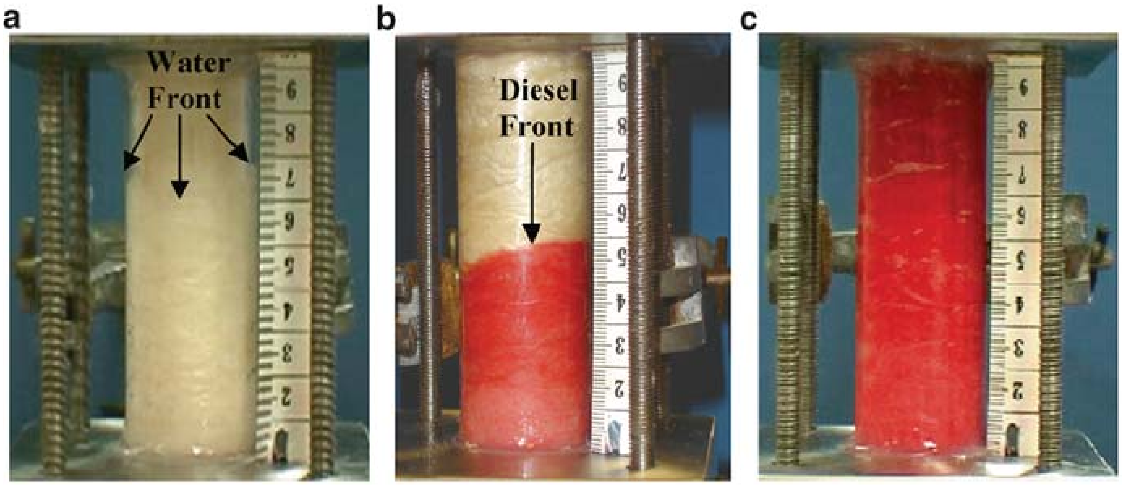

Fig. 13.3 Observation of the 2.5 % diesel/water separation by kapok filter with packing density of 0.07 g/cm^3: (**a**) water front advancement, (**b**) diesel front advancement, and (**c**) filter column at breakthrough (Lim and Huang 2007b) Copyright 2007, reproduced with permission from Elsevier

with an increase in packing densities and oil concentration, the hydraulic conductivities will decrease (Huang and Lim 2006). During this process, the kapok filters can also reduce the COD and turbidity of effluent for the oily water (Rahmah and Abdullah 2010), and can retain stable after 15 cycles of reuse with only 30 % of sorption capacity reduction (Abdullah et al. 2010). Owing to its impressive hydrophobicity, kapok fiber shows poor affinity to water and good affinity to all kinds of oils. This fiber shows a high adsorption capacity for diesel oil (31 ± 0.81 g/g) (Zhou et al. 2010), and can selectively absorb abundant amount of oil (40 g/g) from an oily water in both freshwater and seawater (Hori et al. 2000). Even in the well-mixed oil–water media, kapok fiber shows its effective oil-absorbing performance. In that case, the kapok fiber shows overwhelmingly high oil-to-water sorption (O/W) ratios ranging from 19.35 to 201.53, far superior to sugarcane bagasse, rice husks, and synthetic sorbent (lower O/W ratios of 0.76–2.69) (Ali et al. 2012). Given the mechanical property, an oil-absorbing composite material by mixing pig hair with kapok fiber has been developed. Flexibility of pig hair is larger than the kapok fiber, making the composite show a higher elasticity (Liu et al. 2012).

Kapok fiber is a highly effective oil-absorbing material and its sorption mechanism can be proposed as follows. Owing to its hollow structure and waxy surface, the kapok fiber has intrinsic larger effective pore volume for oil entrance and higher adherence ability for oils against escape. Due to the better compatibilities between the oils and the wax layer of the kapok fiber, the oils are firstly adsorbed by the interactions and van der Waals forces between the oils and the waxy surface. Subsequently, the oils previously entered the kapok assemblies will penetrate into the kapok lumens via internal capillary movement. During the entire process, two dominant factors that contribute to the oil absorption and retention within the kapok assemblies should be taken into account: one is the oleophilicity of the kapok fiber and the other is the physical characteristics of oils such as density, viscosity, surface tension (against air), and contact angle with the kapok surface (Lim and Huang 2007a).

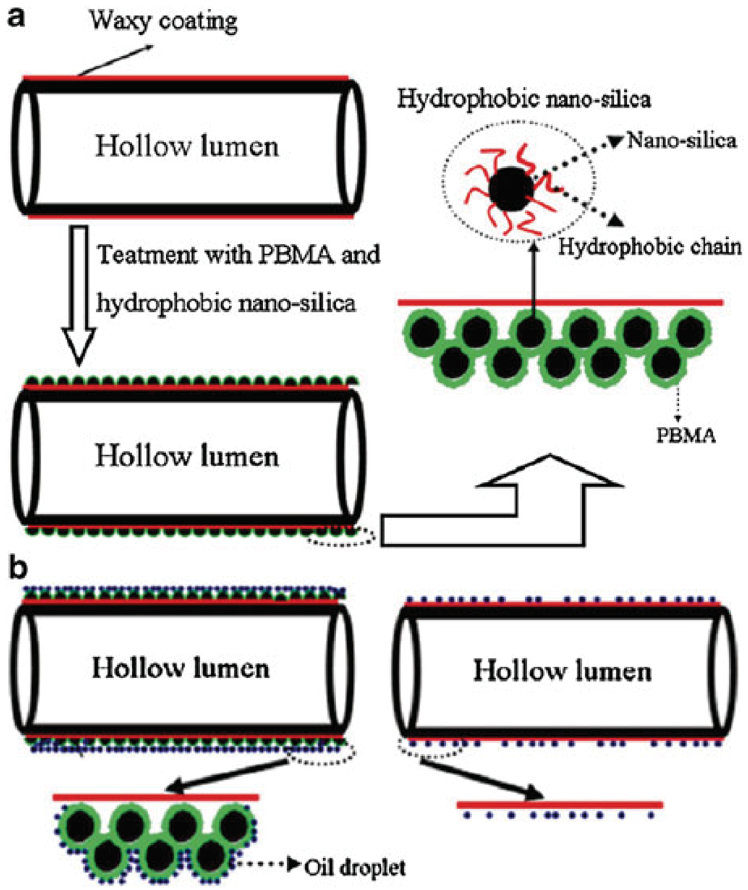

Fig. 13.4 (**a**) Schematic representation of transition from raw fiber to coated kapok fiber with surface of nanometric roughness and low surface energy and (**b**) Schematic mechanism of oil droplet on surface of raw and coated kapok fiber (Wang et al. 2013d) Copyright 2013, reproduced with permission from Elsevier

For the oil absorption and retention, the hydrophobic–oleophilic characteristic of the surface of kapok fiber has made great contributions. To find more chances for the application of kapok fiber in oil spillage control, kapok fiber can be amenable to surface modification by giving appropriate treatment. To enhance the oil absorbency, kapok fiber can be modified with materials with low surface free energy to obtain hydrophobic surface, by which the resulting kapok fiber can be afforded with new lipophilic properties. Using polybutylmethacrylate (PBMA) and PS as the modification agents, Wang et al. (2013a) prepared two kinds of oil absorbers via a facile solution–immersion process and found that PBMA- and PS-coated kapok fibers show higher oil-absorbing capacities than raw kapok fiber for gasoline, diesel, soybean oil, and paraffin oil and the oil sorption capacity can reach up to 80 times their weight. In addition, the kapok fiber can be used as the filler to construct a kind of network with a low crosslinking and a loose structure for synthetic sorbent materials in order to improve the oil absorbency (Wang et al. 2013b). Grafting copolymerization or esterification modification is also useful to increase the hydrophobicity of kapok fiber to enhance its oil sorption capacity (Wang et al. 2012a, 2013c).

Furthermore, the oil sorption capacity of kapok fiber can be improved by transforming its silky surface into rough surface by constructing hierarchical micro- or nanostructures (Wang et al. 2013d). As schemed in Fig. 13.4, with the assistance of hydrophobic–hydrophobic effect, hydrophobic nano-silica is firstly dispersed into the PBMA solution, and the resulting mixture is then coated on the surface of kapok

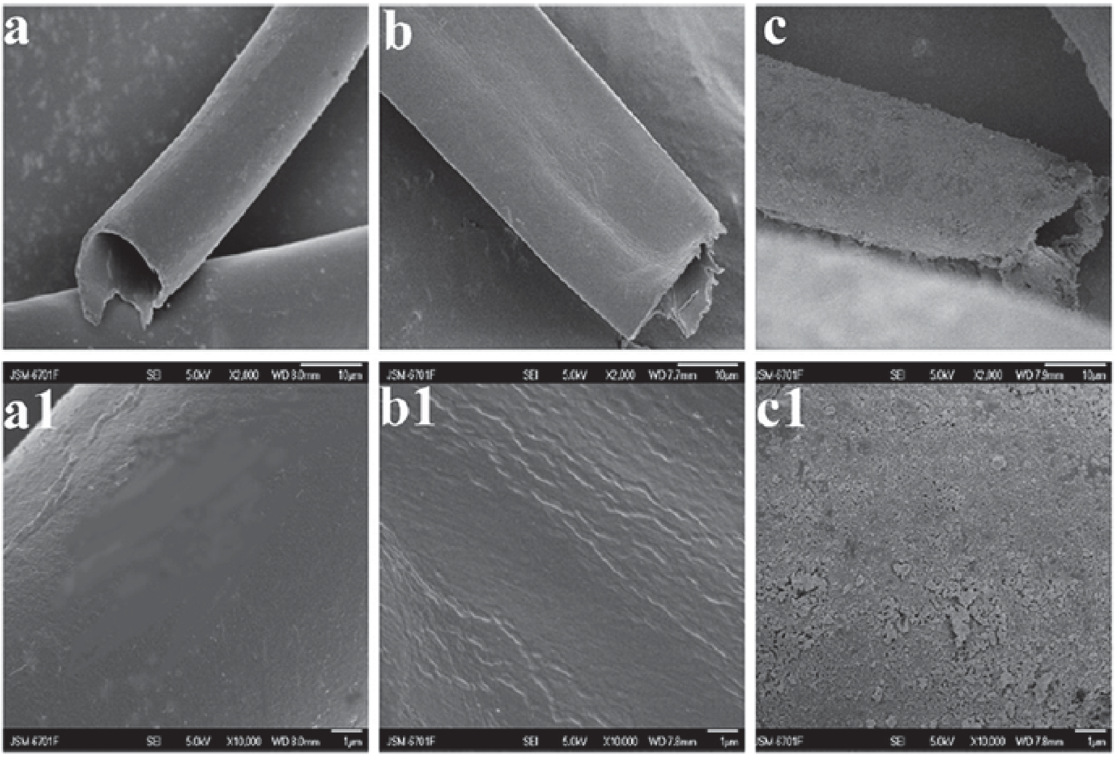

Fig. 13.5 SEM micrographs of (**a**, **a1**) raw, (**b**, **b1**) treated, and (**c**, **c1**) superhydrophobic kapok fiber (Wang et al. 2012b) Copyright 2012, reproduced with permission from Elsevier

fiber, by which a new surface with hierarchical micro and nanostructures is formed. This rough surface, which appears from the combination of more silica nanoparticles and PBMA deposit sediment with low surface energy, can provide more hydrophobic micro-areas that will facilitate the oil retention in kapok fiber. Therefore, more oils can be entrapped into the kapok fiber, which are not easily escaped from the constructed surface of kapok fiber. From hydrophobicity into superhydrophobicity, the surface of kapok fiber can also be coated by a facile incorporation of silica nanoparticles and subsequent hydrolyzation of dodecyltrimethoxysilane (DTMS) for hydrophobic modification (Wang et al. 2012b). As shown in Fig. 13.5, the raw kapok fiber shows a smooth and waxy surface, while the $NaClO_2$-treated kapok fiber exhibits a rough surface with subtle textures and wrinkles. This is attributed to the fact that after $NaClO_2$ treatment, the coverage of inherent plant wax layer on kapok fiber has been removed and more cellulose hydroxyl groups have been exposed to transform the fiber surface from hydrophobic to hydrophilic. Different from raw and $NaClO_2$-treated kapok fiber, the surface of hydrophobical modification of kapok fiber is covered with dense silica nanoparticles and among these nanoparticles, no any interstices can be observed from the SEM images. Though more silica nanoparticles are found on the external surface of kapok fiber, they do not block the internal hollow lumen, allowing those open lumens to retain their intrinsic oil sorption capacity. Compared with raw kapok fiber, this modified fiber shows an excellent oil sorption capacity and an improvement of 46.6 and 20.2 % have been reported for diesel and soybean oil. Furthermore, this coated fiber exhib-

Table 13.1 Kapok fiber-based oil-absorbing materials

Materials	Systems	Oil type, absorbency (g/g) or removal ratio (%)	References
Raw kapok fiber	Static	Machine oil, 40	Hori et al. (2000)
Raw kapok fiber	Static	Diesel oil, 31 ± 0.81	Zhou et al. (2010)
Raw kapok fiber	Static	Diesel oil, 19.35; crude oil, 25.71; new engine oil, 60.51; used engine oil, 49.94	Ali et al. (2012)
Raw kapok fiber	Static	Toluene, 30.4; chloroform, 40.2; xylene, 29.2; *n*-hexane, 21.1; gasoline, 34.1; diesel, 38.9; soybean oil, 50.6; paraffin oil, 54.3	Wang et al. (2012c, 2013a)
Raw kapok fiber	Static	Diesel oil, 36; hydraulic oil, 43; engine oil, 45 at 0.02 g/cm^3	Lim and Huang (2007a)
Raw kapok fiber	Static	Diesel oil, 36.7; used engine oil, 50.8; new engine oil, 47.4 at 0.02 g/cm^3	Abdullah et al. (2010)
Raw kapok fiber	Static	High density oil, 12.6; diesel oil, 11.8 with the porosity of 0.95	Rengasamy et al. (2011)
HCl-treated kapok fiber	Static	Toluene, 35.5; chloroform, 51.8; xylene, 34.8; *n*-hexane, 25.2	Wang et al. (2012c)
$NaClO_2$-treated kapok fiber	Static	Toluene, 36.4; chloroform, 52.3; xylene, 35.5; *n*-hexane, 26.2	Wang et al. (2012c)
PBMA-coated kapok fiber	Static	Gasoline, 59.5; diesel, 64.9; soybean oil, 83.2; paraffin oil, 80.3	Wang et al. (2013a)
PS-coated kapok fiber	Static	Gasoline, 62.3; diesel, 67.8; soybean oil, 80.3; paraffin oil, 83.3	Wang et al. (2013a)
PBMA/SiO_2 coated kapok fiber	Static	Diesel oil, 64.5; soybean oil, 87.1; crude oil, 68.3; 150SN, 77.9; 20cst, 82.3	Wang et al. (2013d)
Acetylated kapok fiber	Static	Diesel oil, 34.1–35.9; soybean oil, 49.8–53.9	Wang et al. (2013c)
Superhydrophobic kapok fiber	Static	Diesel oil, 46.9; soybean oil, 58.8	Wang et al. (2012b)
kapok-*g*-polystyrene	Static	Chloroform, 65.4; toluene, 43.2	Wang et al. (2012a)
PBMA/KF composite	Static	Toluene, 14.6; chloroform, 26.0 with 8 % KF	Wang et al. (2013b)
Raw kapok fiber	Deep-bed filtration	100 % for diesel/water mixture and >99.4 % for hydraulic oil/water mixture	Huang and Lim (2006)
Raw kapok fiber	Deep-bed filtration	>99 % in 2.5 % diesel/water influent	Lim and Huang (2007b)

its excellent oil/water selectivity for cleaning up oils over the water. Table 13.1 summarizes some kinds of oil-absorbing materials based on kapok fiber including raw, pretreated and modified.

13.2.5 Template Material

With kapok fiber as the natural fine template, Zhang et al. (2010) have successfully fabricated a series of microtubes with high length/diameter ratio and controllable morphology. This facile fabrication method has been used for the preparation of many kinds of organic and inorganic materials with controllable wall thickness. Using kapok fibers as the matrix, kapok fiber/magnetic nanocomposites and kapok fiber/CdS nanocomposites are prepared through in situ composition (Tang et al. 2008, 2012), which has a significant guiding role to the preparation and structure characterization of cellulose/inorganic nanocomposites based on plant cellulose resources. Besides, kapok fiber can guide the growth orientation of polyaniline via in situ rapid polymerization of aniline. The resulting material exhibits a unique kapok fiber-aligned morphology and a faster adsorption rate for an adsorbate (Zheng et al. 2012a, b).

13.2.6 Support Material

Kapok fiber is a natural cellulosic fiber which is consisted of abundant microtubes with round hollow structure. Kapok fiber has large hollow structure and contact surface area, and such structure characteristics allow the catalyst to be accessible to the surface of kapok fiber and then a highly effective catalytic reaction can be occurred. Therefore, kapok fiber is expected to be a desirable candidate for catalyst carriers and recovery. Fan et al. (2012) use polyacrylonitrile (PAN) coating to change the surface of kapok fiber from hydrophobic to hydrophilic and improve the adsorption ability for catalytic nanoparticles via a cetyltrimethylammonium bromide (CTAB) assisted self-assembly method. During this process, the amount of CTAB can affect the deposition of PAN coating on the fiber surface (Fig. 13.6). Subsequently, the PAN coated kapok fiber can be used as the support for Au nanoparticles, and the resulting material shows promising catalytic ability for reduction reaction of 4-nitrophenol in the presence of $NaBH_4$.

Kapok fiber can also adsorb an extractant during the metal solvent extraction and behave as the support for the impregnated metal adsorbent. Higa et al. (2011) employed 2-ethylhexyl phosphonic acid mono-2-ethylhexy ester as the extractant to obtain a solvent impregnated kapok fiber, with the findings that the kapok fibers possess a higher impregnation ability for the extractant than conventional solvent impregnated resins, such as crosslinked polystyrene and crosslinked polymethacrylic ester, and thus solvent impregnated kapok fibers have a higher adsorption ability for Eu(III) with the maximum adsorption of 0.685 m mol/g. By comparing bis(2-ethylhexyl)phosphoric acid (D2EHPA) impregnated kapok fiber (SIF) with D2EHPA impregnated resin using XAD7HP as the support (SIR) and solvent extraction with D2EHPA dissolved in a nonpolar organic solvent (SX), the removal percentage of Bi(III), Cd(II), Co(II), Cu(II), Fe(III), Ni(II), Pb(II), and Zn(II) from an aqueous nitrate medium was evaluated, with the findings that SIF is more advantageous over SIR and SX according to the amount of D2EHPA necessary for achieving a certain removal percentage. Therefore, kapok fiber-supported SIF will find potential applications in metal-containing wastewater treatment (Huynh and Tanaka 2003).

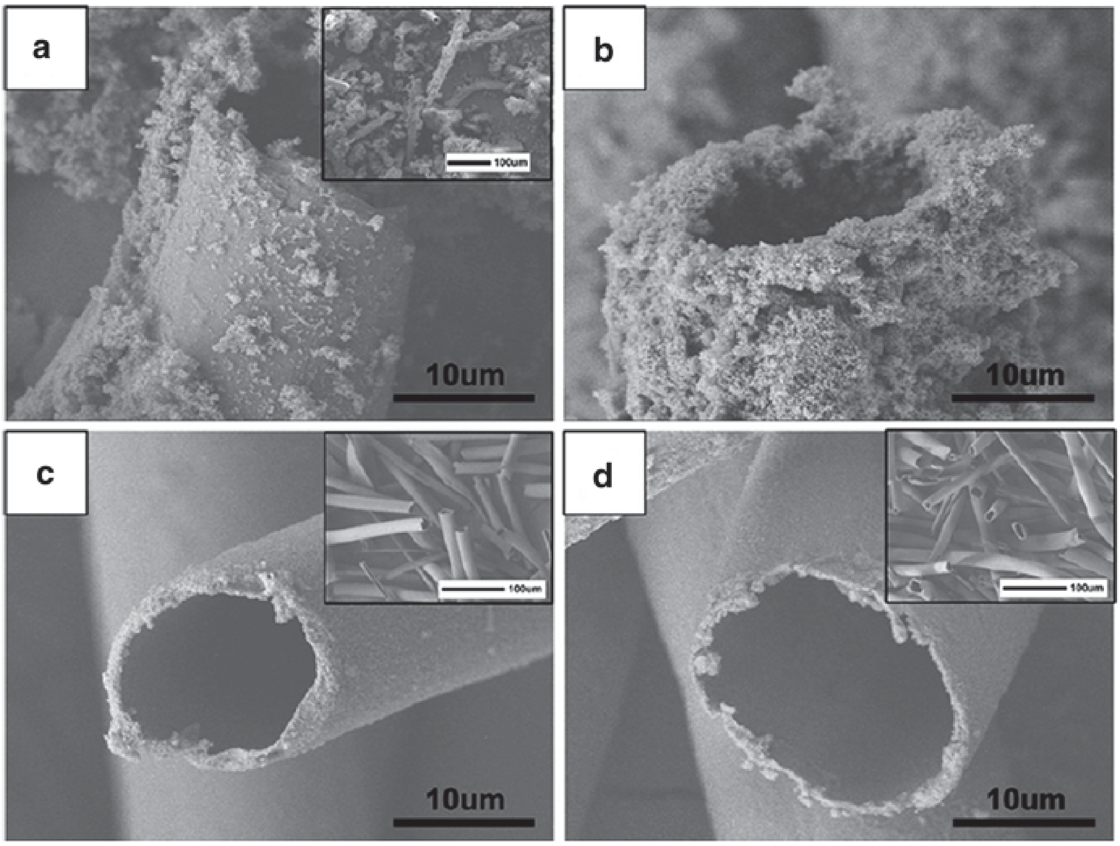

Fig. 13.6 SEM images of the prepared kapok–PAN composite microtubes using varying amounts of CTAB: (**a**) 4.0, (**b**) 7.5, (**c**) 15.0 and (**d**) 30.0 mg, respectively. The amount of AN was fixed at 1.5 mL. *Insets* are the tubes in a low magnification, and the scale bar is 100 µm (Fan et al. 2012) Copyright 2012, reproduced with permission from Elsevier

13.2.7 Reinforcement Material

Plant fibers as the easily renewable sources have attracted much attention in recent years. They are rich in cellulose and cheap in price, and have shown potential application as reinforcements to thermoset and thermoplastic polymer matrices. Plant fibers contain an abundant of hydroxyl groups, making them be highly polar. Accordingly, plant fibers can interact with the resin matrices to form hydrogen bonds. However, those hydroxyl groups are hindered from reacting with resin matrices because of the coverage of the surface of plant fibers with pectin and wax layer, which will result in mechanical interlocking adhesion between the surface of plant fibers and resin matrices. To expose the reactive hydroxyl groups and construct a rough surface, plant fibers generally suffer from a physical and/or chemical treatment or modification.

Alkali treatment is generally used to remove lignin, pectin, wax, and natural oils covering the outer surface of the plant fibers to improve the surface and mechanical properties for further application. In this case, sodium hydroxide has been widely used for treating the surface of plant fibers. By NaOH treatment, the chemical composition of cellulose in kapok fiber cannot be significantly affected, but the crystalline cellulose will be reduced as a result of partial transform of cellulose I to cellulose II. This process is known as alkalization (mercerization) (Mwaikambo and Ansell 2002). Acetylation is another attractive method for modifying the surface of kapok fiber, making it more hydrophobic. With and without an acid catalyst, acetyl groups can be grafted onto the cellulose structure of plant fibers to reduce the hydrophilic tendency. Alkalization and acetylation can successfully change or modify the structure of natural plant fibers to improve the performance of plant fiber composites for better adhesion to resin matrices (Mwaikambo and Ansell 1999; Mwaikambo and Bisanda 1999).

As one kind of important lignocellulosic plant fibers, kapok fiber has been used as the reinforcement material in polyester matrix by hybridizing with glass and sisal fabrics (Reddy et al. 2008). Compared with kapok/sisal polyester composites, the properties of kapok fiber/polyester composites are more attractive (Reddy et al. 2009). For cotton–kapok fabric–polyester composites, with increasing the volume fraction of kapok fiber, the flexural strength and modulus are also increasing. This result implies that the cotton–kapok fabric–polyester composites will find promising industrial applications as design applications frequently involve a bending rather than tensile mode (Mwaikambo and Bisanda 1999; Mwaikambo et al. 2000). The addition of kapok fiber into the thermoplastic cassava starch (TPCS) can not only reduce the water absorption of the TPCS/kapok fiber composite, but also enhance its stress at maximum load and Young's modulus (Prachayawarakorn et al. 2013).

13.2.8 Pulping and Papermaking

Under the optimal dosage of sodium hydroxide, kapok fibers were firstly cooked and the resulting pulp was then refined with two passes using a disc refiner for further blending with commercial hardwood pulp and/or softwood pulp to make papers. The experimental results indicate that the incorporation of kapok pulp into the mixed pulps is beneficial for the improvement of tensile and burst strengths of the sheets, but unbeneficial for the tear resistance and elongation. Moreover, by mixing kapok pulp with the commercial pulps, the water repellency of the sheets is shown to improve. Therefore, it is concluded that kapok fiber will be a quality pulp source for papermaking, and will receive special attentions in packaging paper requiring strength and water repellency (Chaiarrekij et al. 2012).

13.2.9 Kapok-Derived Activated Carbon Fibers

In recent years, activated carbon fibers have attracted much attention as versatile materials having potential as a novel adsorbent, catalyst, and so on. Up to now, numerous research activities have further exploited the preparation of activated carbon fibers based on abundant natural plant fibers, such as kapok fiber. Some studies have been performed to obtain kapok-derived activated carbon fibers with or without an activation process. The experimental results demonstrate that with the assistance of activation process, the kapok-derived activated carbon fibers have a higher surface area and larger hollow pore volume (Chung et al. 2013; Wang et al. 2008).

These kapok-derived activated carbon fibers can be applied for the adsorption of methylene blue and phenol from an aqueous solution (Rong and Zhou 2009).

13.2.10 Kapok-Derived Biofuel

Recently, biofuels such as biodiesel and bioethanol have attracted the most attention for their potential renewable characteristics. However, the first-generation bioethanol is derived from edible sources that will result in food and fuel conflict from the viewpoint of food security. In this respect, bioethanol refined from lignocellulosic biomass such as agricultural residues offers a great option. This kind of bioethanol is recognized as the second-generation bioethanol, which is generally obtained by three main steps: (1) pretreatment, (2) enzymatic hydrolysis, and (3) ethanol fermentation.

Owing to its high glucose content, kapok fiber may be a potential resource for the production of second-generation bioethanol. Before a pretreatment, only 0.8 % of reducing sugar was obtained by enzymatic hydrolysis. After a pretreatment by water, acid, or alkaline, 39.1, 85.2, and >100 % of reducing sugar was produced. For the conversion of cellulose in kapok fiber into glucose, the maximum obstruction is believed to be the high hemicellulose and lignin contents. The acid treatment can remove only hemicellulose, while the alkaline pretreatment enables the removal of both hemicellulose and lignin. Therefore, alkaline pretreatment is more effective for the production of reducing sugar for that lower lignin content is more favorable for enzymatic hydrolysis as the presence of a large number of lignin will adsorb more enzymes to reduce their activity (Tye et al. 2012).

13.2.11 Other Applications

In recent years, renewable green resources are gaining more and more interests. As we have addressed, kapok fiber, as an abundant natural plant fiber, has been used widely for various industrial fields. However, kapok fiber is nonresistant to spark or flame. To remove the combustible compounds, the kapok fiber has been treated by using gamma ray. During this process, the functional groups as methoxyl group in kapok fiber can also be cleaved in addition to the removal of combustible compounds (Chung et al. 2009), by which kapok fiber has been converted into a flame-resistant fiber, but the fine hollow lumen is still present.

Due to the presence of a large proportion of lignin, ordinary cellulolytic bacteria are difficult to attack the kapok fiber. Therefore, kapok fiber can be used as a reference to investigate some properties of wood fibers as its chemical resemblance to wood fibers. Generally, it is time-consuming for preparing the wood sections for microscopic observation, whereas kapok fiber can be observed easily without sectioning. Therefore, it is possible using kapok fiber as a reference for enriching or purifying the wood-degrading bacteria (Nilsson and Björdal 2008).

13.3 Conclusions and Future Perspective

As an eco-friendly renewable material, kapok fiber has received increasing attention in recent years for its intrinsic superiorities, especially by combining its higher hollowness and hydrophobic–oleophilic characteristics. However, the difficulty in spinning of kapok fiber remains in limiting its fabrication for broader applications, especially as the oil-absorbing materials, an overwhelming product for kapok fiber. The development of novel technologies or methods based on kapok fiber will in future promote the further utilization of this natural fiber. Moreover, the unique structure of kapok fiber can direct to design and construct more materials for application in different fields.

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