Chemistry of fiber polymer, synthesis and reaction

Research project

Submitted to the department of (chemistry) in partial fulfillment of the Requirements for the degree of BSc . in (chemistry)

By:

Sara karim sabr

Supervised by:

Darya Jaleel Raheem

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

قَالُواْ سُبْحَٰنَكَ لَا عِلْمَ لَنَآ إِلَّا مَا
عَلَّمْتَنَآۖ إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ

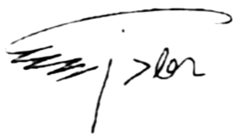
صدق الله العظيم

البقرة (32)

DECLARATION

I’m the student supervisor (Sara Karim Sabr) I Supported that the student completed all the requirements for submitting the research drown entitled (Chemistry of fiber polymer, synthesis and reaction) according to the numbered administrative order 3/1/5/1972 on 9th October 2022 in accordance with the instructions of the Salahaddin University Quality assurance and it’s ready for discussion.

Darya Jaleel Raheem



Date :   /   /   2023

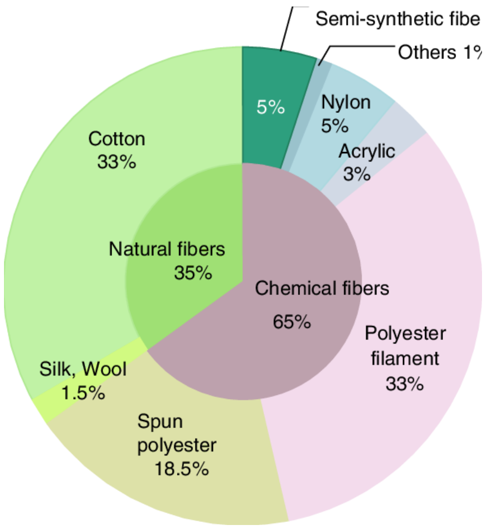
Abstract:

Fibers are one of the most important chassis of polymers. The molecules with regular structure can align themselves very closely for effective utilization of the secondary intermolecular bonding forces, the result is the formation of fiber .fibers are liner polymers with high symmetry and high intermolecular forces that result usually from the presence of polar groups. They are characterized by high modulus, high tensil strength, and moderate extensibilities. We fouces in our research project in some types of the fibers, their synthesis properities andsome of the industrial applications.

Contents

Introduction

Fibers are part of our daily lives. Reflecting on their surroundings can understand their full impact on society, from everyday uses like clothing and carpets to artificial grass, fiber-reinforced composites in sporting goods (rackets, golf clubs, etc.), boats, civil engineering, aerospace and military applications such as aircraft and rocket.



There are many different types of fibers; most of them have diameters greater than one micrometer, and they can be divided into polymer fibers and non-polymer fibers. Polymer fibers include synthetic polymer fibers and natural polymer fibers. Synthetic polymer fibers are made from polymers synthesized from raw materials, like petroleum-based chemicals or petrochemicals. Generally, synthetic polymer fibers are created by forcing, usually through extrusion, polymers through small holes (called spinnerets) into air or other mediums to form filaments. Natural polymer fibers include those produced by plants and animals. They are typically biodegradable and can be classified as natural cellulose fibers and natural protein fibers. Non-polymer fibers are those that are not made from polymers, and include carbon, glass, ceramic, metal, and composite fibers, etc.

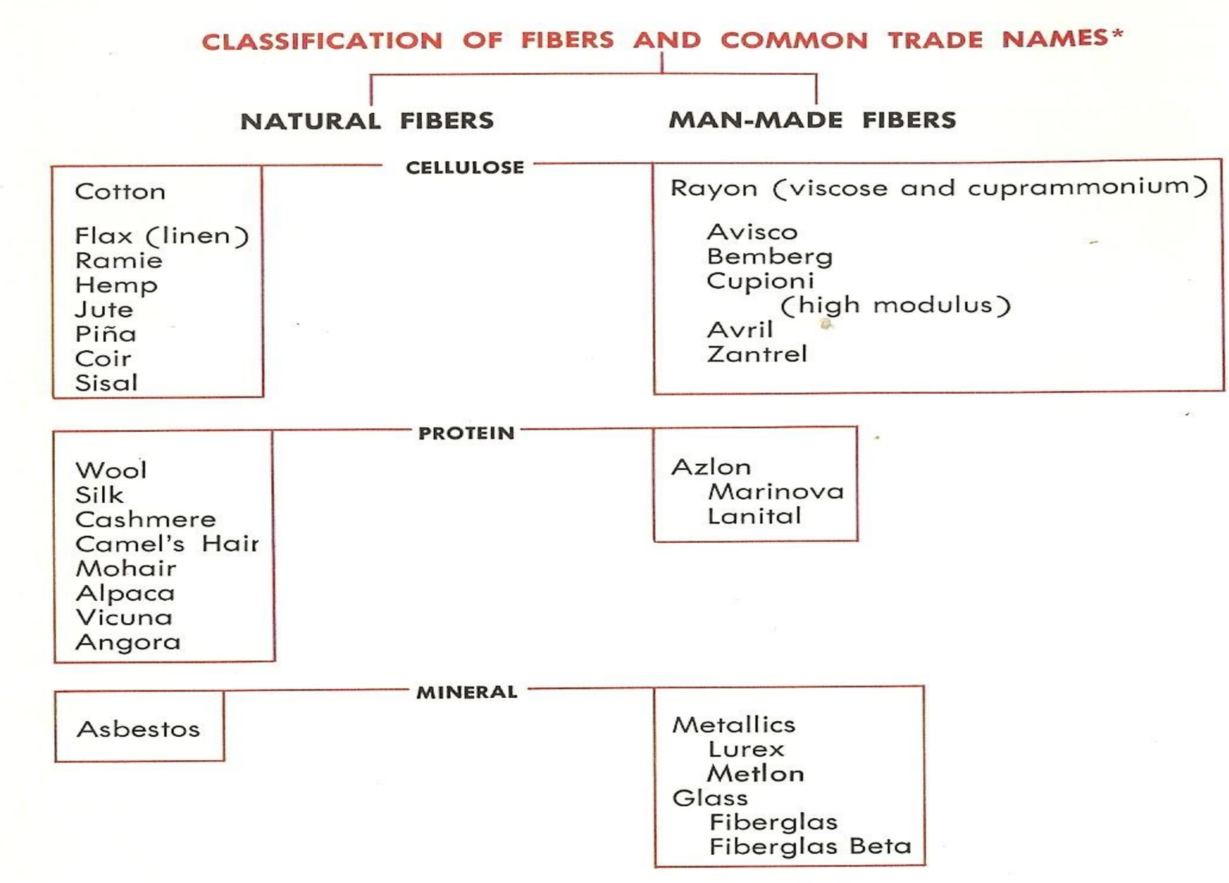
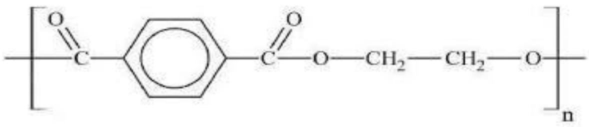


Figure 1. Global fiber production (FY2013 Fiber Handbook) [6]

1) Polyester Fibers

Polyester fibers, which mainly consist of polyethylene terephthalate (PET), make up a large volume of the world's synthetic fiber industry products and somehow dominate the industry. These fibers are inexpensive and are easily obtained from petrochemical sources and have a good range of physical properties. They are durable, lightweight, easily paintable and resistant to wrinkles and have excellent washability. These fibers are used in both continuous and discrete fashion in textile and furniture fabrics, carpets, tires, car seat belts, filters, tents, sails and more.

Although the dominant polymer in these fibers is PET, other polyesters also have their place. Polybutylene terephthalate (PBT) and more recently polyethylene terephthalate (PTT) are used in carpet fibers due to their superior fiber resistance. [3]



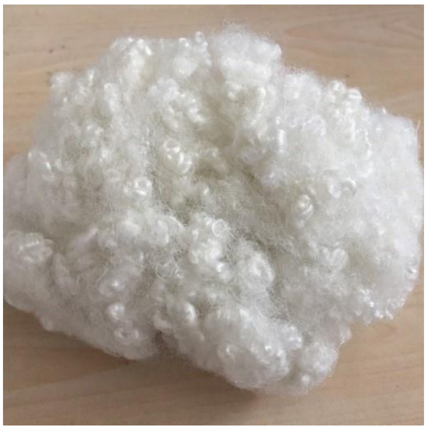


Figure 2. Polyester fibers [7]

Dacron was the first polyester introduced in 1953. It is a long chain polymer composed of 85% by weight an ester of dihydric alcohol and terephtalic acid. The most common application of polyester is in fabrics. Polyester fabric has properties that make it ideal for use as clothing as it is both breathable and stain-resistant. Polyester is typically blended with other natural fabrics to increase comfort and reduce the amount of creasing that is common with polyester.

Figure 3. Various applications of polyester fibers [8]

Figure 4. Application of polyester fibers in geotextile fabrics to reinforce the road bed [9]

Figure 5. Application of polyester fibers in fabric structures [10]

2) Polyamide or Nylon Fibers

Due to their properties, these fibers are widely used in many fields and industries, especially the textile industry. We deal with each of these areas separately.

Structure of Nylon – 6,6

A) textiles

Nylon fibers have properties that make them one of the most popular synthetic fibers. These include high strength as a textile fiber; abrasion, luster, chemicals and oils resistance, water washability, dyeability in a wide range of colors, good elasticity and resilience, smooth, soft, long-lasting fabrics of filament yarns. Because of these properties of nylon fibers are widely used in clothing such as knitwear, socks, underwear, raincoat, ski clothing, windsurfing, swimming and cycling clothing, as well as for home furnishings such as furniture, Upholstery, rugs and curtains are used. A combination of excellent abrasion resistance, appearance and economic agents puts polyamide fibers in a great position in the carpet fibers market and it can be expected that these nylons will still be the most used fibers for carpets.

Figure 6. Carpet made of nylon fibers [11]

B) Industrial Applications

Excellent mechanical properties, fatigue resistance and good tensile strength are the reasons for the superiority of polyamide fibers for industrial applications and for use in truck and aircraft tires. Other uses of these fibers are upholstery fabrics, seat belts, parachutes, ropes, fishing line, nets, sleeping bags, tarpaulins, tents. In addition, high strength, toughness and wear resistance are key factors in the choice of polyamide fibers for a wide range of military applications.

Nylon, like polyester fibers (PET), has a high melting point that works well at high temperatures. Nylon fiber is more sensitive to water than PET. In some cases it is used as a blend fiber because it has excellent tear strength. Overall, the resiliency and wrinkle recovery of a non-woven nylon product is not as good as PET fiber. Because of its toughness, nylon fibers are suitable for flooring.

Also used in Ni-H and Ni-Cd batteries as separators, synthetic suede, thermal insulation, special paper, automotive products, sportswear and conveyor belts.

Figure 7. Nylon fibers [12]

3) Polyolefin Fibers (Polyethylene and Polypropylene)

most natural or synthetic fibers in general commercial use are organic structures with a carbon-carbon chain backbone. Basically polyolefin polymers have high molecular mass, aliphatic and saturated hydrocarbons, some of which can be easily fused.

A typical polyolefin fiber density range is from 0.90 to 0.96 gr/cm3 and shows extremely low moisture regain. Polyolefin fibers, thus, are suitable choices for applications requiring aquatic buoyancy and negligible moisture regain, such as mooring ropes, oil spill booms, and fishing nets, etc.

Polyolefin fibers have good tensile properties, good abrasion resistance and excellent resistance to chemicals, mildew, micro-organisms, and insects. Polyolefin textile structures show good wicking action, high insulation and are comfortable to the skin, which are significant factors for active sportswear and protective clothing.

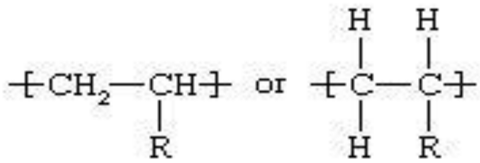


Figure 8. Different applications of polypropylene fibers in textile [13]

However, polyolefins have problematic properties for specific applications. For example, due to the low melting point, polyethylene C125-120 ° C and polypropylene C165-160 ° C cannot be used at high temperatures. These fibers are not usable on exterior surfaces; since polyolefins are susceptible to photosynthetic degradation, they have low resistance to dehydration at temperatures above 100 ° C, are difficult to dye and have limited shade of color. The olefins also have high flammability, low resilience, and stress-induced creep.

A / Use of polyolefin fibers in medical textiles

Polyolefin, PP in particular, exhibits excellent chemical resistance and chemical inertness. These properties are prerequisites for medical and surgical applications. Fibrous structures for medical applications also require a combination of strength, flexibility, and controlled moisture and air permeability. Materials for these applications can be classified into four specialized areas:

- non-implantable materials – wound dressing, bandages, plasters, etc.
- extracorporeal device – artificial kidney, liver and lung
- implantable materials – sutures, surgery meshes, vascular grafts, artificial joints, artificial ligaments
- healthcare/hygiene products – bedding, diaper, surgical gowns, wipes, etc

Figure 9. Widespread application of polyolefin fibers in medicine [14]

For non-implantable material applications, knitted, woven or nonwoven polyethylene fabrics are used in wound contact areas and wound care products. In some orthopaedic bandages, woven or nonwoven fabrics made of polypropylene fibers are used. Knitted, woven, or nonwoven polypropylene fabrics can serve as reinforcements for plasters. For implantable applications, non-bioabsorbable sutures are typically made of PP fibers by braiding. Surgery meshes, for example hernia meshes. Healthcare/hygiene products are mainly based on PP nonwovens. The largest single fiber application for PP is nonwoven fabrics. There are three different types of nonwoven structures of PP for this application: spunbonded (SB), melt-blown (MB) and thermal-bonded carded webs. The latter is mainly used for diaper linings in a similar fashion to SB nonwovens. Disposable diaper and incontinence control applications are the largest single PP nonwoven fabrics market. Hospital gowns, uniforms, and surgical gowns are mainly disposable because of the high cost of laundering and sterilization. Thus, PP nonwovens are ideal for this application.

B / Use of polyolefin fibers in filtration

A wide variety of industrial processes requires the separation of solids from liquids (suspension) or gas (aerosol) for purifying products, saving energy raising process efficiency, recovering precious materials, and improving pollution control system, etc. For example, air filters are used for separating suspended solid particles (soot) or liquid droplets (aerosol) in air. Filter media fabric design must be based on the performance properties such as the length of service life, physical and chemical condition of the operation. The design criteria cannot be overemphasized because filter fabric failure during service could result in lost production cost, loss of product,

heavy maintenance cost and added environmental pollution. The fibrous filter media are fabricated in woven, knitted, nonwovens or their combinations to meet the performance criteria. Filtration mechanisms are: interception, inertial deposition, Brownian motion, electrostatic, and gravitational. One of the earliest applications for polyethylene yarns was in the production of industrial filtration fabrics. The range of properties offered by polyethylene is particularly suitable for this application, and PE fiber is being used increasingly for this purpose. The polyethylene yarns are used for industrial filtration fabrics owing to the following features:

- The high wet strength of PE fibers and PE fabrics are not weakened during the filtration of water solutions.
- The excellent resistance of polyethylene to a wide range of chemicals and solvents used for filtration of industrial liquids.
- The high abrasion resistance of polyethylene enables the fabrics to withstand considerable abrasion during filtration.
- Polyethylene is particularly good in cake release. Solid particles are built up into cakes between the layers of filters during the filtration of industrial liquids. These cakes are removed perhaps many times a day by opening the filter presses, and it is important that the solid material should come away cleanly and easily from the filter fabric.
- The complete resistance of polyethylene to attack by micro-organisms is of great value

in many filtration applications, such as the filtration of sewage.

- Dimensional stability.
- Low cost. [5]

Figure 10. Polyethylene fibers [15]

Figure 11. Polypropylene fibers [16]

4) Acrylic Fibers

Most of the growth in the use of acrylic fibers is due to its replacement with wool. Acrylic has many of the desired properties of wool, yet it is superior in many areas where wool is deficient. Acrylic fibers such as wool are valuable because of their warmth, softness of hand, generous bulk and pile qualities, and ability to recover from stretching. Acrylics, meanwhile, are less expensive, more resistant to abrasion and chemical attack, and more stable toward degradation from light and heat. In addition, acrylics are not attacked by moths and biological agents and show very little of wool's tendency to felt. [4]

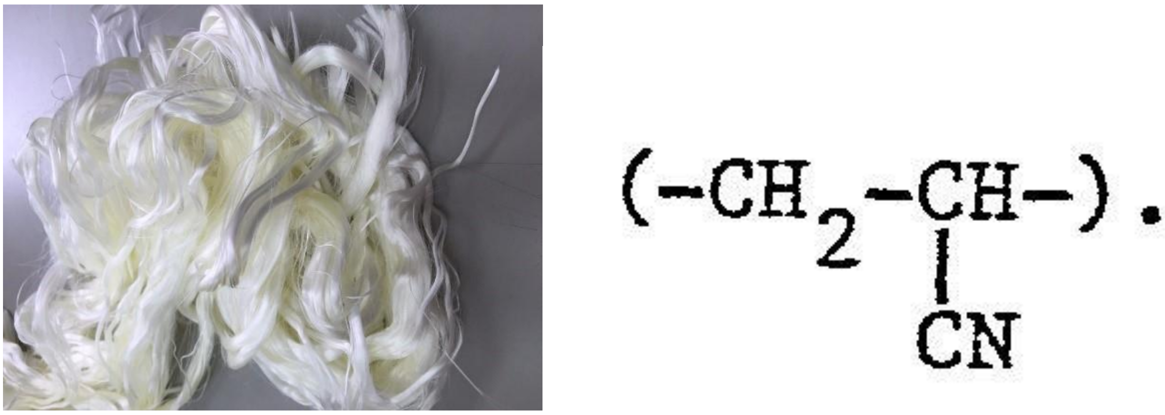


Figure 12. Acrylic fibers [17]

Acrylics, in stiff competition with nylon, polyester and polyolefin, have penetrated only markets where they have a clear advantage in critical properties. For example, acrylics are clearly superior in resistance to sunlight. This makes continuous filament acrylics valuable in outdoor applications, such as convertible tops, tents, and awnings. Pigmented acrylics can be used in applications where maximum resistance to fading and loss of strength is needed. [4]

Figure 13. Application of acrylic fibers in convertible tops [18]

In applications such as awnings that require high flame resistance, modacrylic fibers are used. Acrylics with low comonomer content are highly resistant to chemical attack and thermal degradation. These properties make acrylics suitable for industrial filters and battery separators. [4]

Figure 14. Application of acrylic fibers in awnings [19]

In the general apparel market, acrylic and modacrylic fibers are used as artificial fur or fur-like fabrics. These fibers are made in coarse deniers with special cross sections and surface modifications (e.g., surface inclusions or roughening) to simulate natural animal hairs. Uniform fabrics and silky fabrics are also produced from continuous filament acrylic and modacrylic yarns. [4]

Figure 15. Application of acrylic fibers in a variety of fabrics [20]

Figure 16. Application of acrylic fibers in artificial fur [21]

Finally, the physical and mechanical properties of polymer fibers are presented in the table below:

Table 1. Physical and Mechanical Properties of Polymer Fibers

Fiber	Density	Tenacity	Modulus	Strain at break	Moisture Retention	Elastic Retention at % Strian
Unit	gr/cm3	gr/denier	gr/denier	%	%	%
Polyethylene (HDPE)	0.95	4.5-8	30	10-20	0	0
Polypropylen	0.9-0.91	2-7.8	50-90	15-50	0	100 at 2%
Acrylic	1.14-1.19	2-3.6	40-75	25-55	1.3-2.5	85-99 at 2%
Polyamide	1.14	4.3-6	16-40	15-40	3.5-5	80-99 at 2%
Polyester	1.38	9	125	25	0.4	100 at 8%

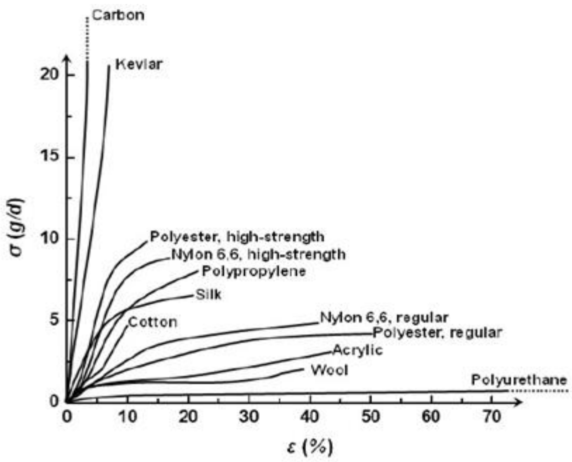


Figure 19. Stress-strain diagram of polymer fibers

Conclusion

In this Research we Conclude

1. There are many different types of fibers; most of them have diameters greater than one micrometer, and they can be divided into polymer fibers and non-polymer fibers. Polymer fibers include synthetic polymer fibers and natural polymer fibers. Natural polymer fibers include those produced by plants and animals.
2. In this research 4 types of fibers were discussed : Polyester Fibers , Polyamide or Nylon Fibers , Polyolefin Fibers (Polyethylene and Polypropylene) , Acrylic Fibers .
3. Polyester Fibers consist of polyethylene terephthalate (PET), make up a large volume of the world's synthetic fiber industry products and somehow dominate the industry. They are inexpensive, lightweight, easily paintable, resistant to wrinkles and easily obtained from petrochemical sources also have a good range of physical properties.
4. Polyamide or Nylon Fibers : are widely used in many fields and industries, especially the textile industry, Nylon, like polyester fibers (PET), has a high melting point that works well at high temperatures. Nylon fiber is more sensitive to water than PET. in this chapter the research is about Textiles and industry applications .
5. Polyolefin Fibers (Polyethylene and Polypropylene) : are organic structures with a carbon-carbon chain backbone. Basically polyolefin polymers have high molecular mass, aliphatic & saturated hydrocarbons, some of which can be easily fused. There use in medical textiles & filtration in industrial processes had been mentioned.
6. Acrylic Fibers : less expensive, more resistant to abrasion and chemical attack, and more stable toward degradation from light and heat. In addition, acrylics are not attacked by moths and biological agents and show very little of wool's tendency to felt. Pigmented acrylics can be used in applications where maximum resistance to fading and loss of strength is needed.

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(Clanton, Schmidt et al. 2001, Ustinovichius, Rasiulis et al. 2012, Senskaia 2019)