

Effect of reinforcement of keratin fiber on hdpe essay sample



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1. 1 Motivation

Until the beginning of the nineteenth century, the materials developed, manufactured and used, whether homogeneous or composite, were basically inorganic in nature. Complex organic substances such as coal and oil were subjected to destructive processes to produce simpler chemicals such as coal gas and gasoline. However, during the twentieth century, organic chemists have developed the means of reversing this destructive process and of creating from the by-products materials that do not occur naturally. Most important among these new substances are the 'super-polymers', commonly called 'plastics', a term which in many cases is misleading, and the production of these materials has increased dramatically since the Second World War.

The possibilities of using these plastic materials in engineering situations are now being extensively examined, and in the field of structural engineering such development is taking place mainly in their use as glass fibre-reinforced plastics, the plastic material most widely used being polyester resin. A large number of materials, e. g. jute, asbestos, carbon and boron, have been used for the fiber reinforcement of the plastic matrix, the main function of the fibers being to carry the majority of the load applied to the composite and to improve the stiffness characteristics of the polymer matrix.

The most widely used material for the reinforcement of polymer is glass fiber in all its various forms, partly because of its high strength and its low specific gravity, partly because of its chemical inertness, and partly because of its being relatively inexpensive to produce. Notwithstanding these,

development of new higher modulus fibers such as boron, graphite, silicon carbide, and beryllium gives us reinforcements having several times the modulus of elasticity of glass fibers with densities as low as or lower than glass and strengths close to that of glass fibers. In addition to having available new chemical types of fibers, there are also a number of options with regard to fiber diameter, fiber length, and grouping of filaments into strands, roving, and yarn. These types and forms of fibers give us a new degree of freedom in terms of being able to select the most appropriate type fiber for a given application.

1. 2 Relevance of the Present Study

A key feature of fiber composites that makes them so promising as engineering materials is the opportunity to tailor the materials through the control of fiber and matrix combinations and the selection of processing techniques. Matrix materials and fabrication processes are available that do not significantly degrade the intrinsic properties of the fiber. In principle, an infinite range of composite types exists, from randomly oriented chopped fiber based materials at the low property end to continuous, unidirectional fiber composites at the high-performance end. Composites can differ in the amount of fiber, fiber type, fiber length, fiber orientation, and possibly fiber hybridization. In general, short-fiber composites are used in lightly loaded or secondary structural applications, while continuous fiber-reinforced composites are utilized in primary applications and are considered high-performance structural materials. By nature, continuous-fiber composites are highly anisotropic. Maximum properties can be achieved if all the fibers are

aligned in the fiber-axis direction. The properties, such as modulus and strength, decrease rapidly in directions away from the fiber direction.

One of the outstanding characteristics of the rapidly increasing technology of composite materials is the almost unlimited freedom of choice that presents itself to the designer. Since not only the number of constituent in a composite materials but also their distribution and orientation within a given structural shape are subject to choice and can possibly lead to identical performance characteristics, it is one of the foremost requirements for developing the technology to also provide avenues for making this choice an intelligent one.

1. 3 Background

The most primitive composite materials were straw and mud combined to form bricks for building construction. The ancient brick-making process can still be seen on Egyptian tomb paintings in the Metropolitan Museum of Art. The most advanced examples perform routinely on spacecraft in demanding environments. The most visible applications pave our roadways in the form of either steel and aggregate reinforced Portland cement or asphalt concrete. Those composites closest to our personal hygiene form our shower stalls and bath tubs made of fiberglass. Solid surface, imitation granite and cultured marble sinks and counter tops are widely used to enhance our living experiences.

The recognition of the potential weight savings that can be achieved by using the advanced composites, which in turn means reduced cost and

greater efficiency, was responsible for this growth in the technology of <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

reinforcements, matrices and fabrication of composites. If the first two decades saw the improvements in the fabrication method, systematic study of properties and fracture mechanics was at the focal point in the 60's. There has been an ever-increasing demand for newer, stronger, stiffer and yet lighter-weight materials in fields such as aerospace, transportation, automobile and construction sectors.

Composite materials are emerging chiefly in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries. These materials have low specific gravity that makes their properties particularly superior in strength and modulus to many traditional engineering materials such as metals. As a result of intensive studies into the fundamental nature of materials and better understanding of their structure property relationship, it has become possible to develop new composite materials with improved physical and mechanical properties. These new materials include high performance composites such as Polymer matrix composites, Ceramic matrix composites and Metal matrix composites etc. Continuous advancements have led to the use of composite materials in more and more diversified applications. The importance of composites as engineering materials is reflected by the fact that out of over 1600 engineering materials available in the market today more than 200 are composite.

1. 4 Types of Composite Materials

Broadly, composite materials can be classified into three groups on the basis of matrix material. They are:

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a) Ceramic Matrix Composites (PMC)

b) Metal Matrix Composites (MMC)

c) Polymer Matrix Composites (CMC)

a) Ceramic Matrix Composites:

Ceramic fibers, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications, and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e. g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibers, or whiskers such as those made from silicon carbide and boron nitride.

b) Metal Matrix Composites:

Metal Matrix Composites have many advantages over monolithic metals like higher specific modulus, higher specific strength, better properties at elevated temperatures, and lower coefficient of thermal expansion. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

b) Polymer matrix Composites:

Most commonly used matrix materials are polymeric. The reasons for this are two fold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are

overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications. Polymer composites are used because overall properties of the composites are superior to those of the individual polymers. They have a greater modulus than the neat polymer but aren't as brittle as ceramics.

The most significant advantage of polymer matrix composites (PMCs) derives from the fact that they are lightweight materials with high strength and modulus values. The light weight of PMCs is due to the low specific gravities of their constituents. Polymers used in PMCs have specific gravities between 0.9 and 1.5, and the reinforcing fibers have specific gravities between 1.4 and 2.6 (Mallick, 1993). Depending on the types of fiber and polymer used and their relative volume fractions, the specific gravity of a PMC is between 1.2 and 2, compared to 7.87 for steel and 2.7 for aluminum alloys. Because of their low specific gravities, the strength-to-weight ratios of PMCs are comparatively much higher than those of metals and their composites (Table 2.1). Although the cost of PMCs can be higher than that of many metals, especially carbon or boron fibers are used as reinforcements, their cost on a unit volume basis can be competitive with that of the high performance metallic alloys used in the aerospace industry.

A second advantage of PMCs is the design flexibility and the variety of design options that can be exercised with them. Fibers in PMC can be <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

selectively placed or oriented to resist load in any direction, thus producing directional strengths or moduli instead of equal strength or modulus in all directions as in isotropic materials such as metals and unreinforced polymers. Similarly, fiber type and orientation in a PMC can be controlled to produce a variety of thermal properties such as the coefficient of thermal expansion . PMCs can be combined with aluminum honeycomb, structural plastic foam, or balsa wood to produce sandwich structures that are stiff and at the same time lightweight. Two or more different types of fibers can be used to produce a hybrid construction with high flexural stiffness and impact resistance (Mallick, 1997).

There are several other advantages of PMCs that make them desirable in many applications. They have damping factors that are higher than those of metals, which means that noise and vibrations are damped in PMC structures more effectively than in metal structures. They also do not corrode.

However, depending on the nature of the matrix and fibers, their properties may be affected by environmental factors such as elevated temperatures, moisture, chemicals, and ultraviolet light.

1. 5 Reinforcements

The most common reinforcements are glass, carbon, aramid and boron fibers. Typical fiber diameters range from 5 μm to 20 μm . The diameter of a glass fiber is in the range of 5 to 25 μm , a carbon fiber is 5 to 8 μm , an aramid fiber is 12. 5 μm . Because of this thin diameter, the fiber is flexible and easily conforms to various shapes. In general, fibers are made into strands for weaving or winding operations. For delivery purposes, fibers are wound around a bobbin and collectively called a “ roving”. An untwisted <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

bundle of carbon fibers is called “ tow”. In composites, the strength and stiffness are provided by the fibers. The matrix gives rigidity to the structure and transfers the load the fibers.

Fibers for composite materials can come in many forms, from continuous fibers to discontinuous fibers, long fibers to short fibers, organic fibers to inorganic fibers. Some of the common types of reinforcements include: •

Continuous carbon tow, glass roving, aramid yarn

- Discontinuous chopped fibers
- Woven fabric
- Multidirectional fabric (stitched bonded for three dimensional properties)
- Stapled

1. 6 Types of polymer composites:

Broadly, polymer composites can be classified into two groups on the basis of reinforcing material. They are: A Fiber reinforced polymer (FRP)

B Particle reinforced polymer (PRP)

a) Fiber Reinforced composite

Common fiber reinforced composites are composed of fibers and a matrix.

Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the

reinforcing fibers. The fibers carry the loads along their longitudinal

directions. Sometimes, filler might be added to smooth the manufacturing process, impart special properties to the composites, and / or reduce the

product cost. Common fiber reinforcing agents include asbestos, carbon /

graphite fibers, beryllium, beryllium carbide, beryllium oxide, molybdenum,
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aluminium oxide, glass fibers, polyamide, bio fibers etc. Similarly common matrix materials include epoxy, phenolic resin, polyester, polyurethane, vinyl ester etc. Among these resin materials, polyester is most widely used.

Epoxy, which has higher adhesion and less shrinkage than polyesters, comes in second for its high cost.

b) Particle Reinforced composite

Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum and amorphous materials, including polymers and carbon black. Particles are used to increase the modulus of the matrix and to decrease the ductility of the matrix. Particles are also used to reduce the cost of the composites.

Reinforcements and matrices can be common, inexpensive materials and are easily processed. Some of the useful properties of ceramics and glasses include high melting temp., low density, high strength, stiffness, wear resistance, and corrosion resistance. Many ceramics are good electrical and thermal insulators. Some ceramics have special properties; some ceramics are magnetic materials; some are piezoelectric materials; and a few special ceramics are even superconductors at very low temperatures. Ceramics and glasses have one major drawback: they are brittle. An example of particle - reinforced composites is an automobile tire, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer.

Over the past few decades, we find that polymers have replaced many of the conventional metals/materials in various applications. This is possible

because of the advantages polymers offer over conventional materials. The

most important advantages of using polymers are the

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ease of processing, productivity and cost reduction. Polymer composites have generated wide interest in various engineering fields, particularly in aerospace applications. Research is underway worldwide to develop newer composites with varied combinations of fibers and fillers so as to make them useable under different operational conditions. In most of these applications, the properties of polymers are modified using fillers and fibers to suit the high strength/high modulus requirements. Fiber-reinforced polymers offer advantages over other conventional materials when specific properties are compared. These composites are finding applications in diverse fields from appliances to spacecrafts.

1. 7Bio Fiber Reinforced Composites

A bio-composite is a material formed by a matrix (resin) and a reinforcement of bio fibers (usually derived from plants or cellulose). With wide-ranging uses from environment-friendly biodegradable composites to biomedical composites for drug/gene delivery, tissue engineering applications and cosmetic orthodontics, they often mimic the structures of the living materials involved in the process in addition to the strengthening properties of the matrix that was used but still providing bio compatibility. Bio-composites are characterized by the fact that the bolsters (glass or carbon fiber or talc) are replaced by bio fiber (wood fibers, hemp, flax, sisal, jute...). These bio/bio-fiber composites (bio-Composites) are emerging as a viable alternative to glass-fiber reinforced composites especially in automotive and building product applications.

The combination of bio-fibers such as kenaf, hemp, flax, jute, henequen, pineapple leaf fiber, and sisal with polymer matrices from both <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

nonrenewable and renewable resources to produce composite materials that are competitive with synthetic composites requires special attention. Bio fiber-reinforced polypropylene composites have attained commercial attraction in automotive industries. Bio fiber-polypropylene or bio fiber-polyester composites are not sufficiently eco-friendly because of the petroleum-based source and the non-biodegradable nature of the polymer matrix. Using bio fibers with polymers based on renewable resources will allow many environmental issues to be solved. By embedding bio-fibers with renewable resource-based biopolymers such as cellulosic plastics; polylactides; starch plastics; polyhydroxyalkanoates (bacterial polyesters); and soy-based plastics, the so-called green bio-composites are continuously being developed.

1. 8 Bio Fibers

Bio fibers have recently attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of bio fiber composites has been a subject of interest for the past few years. These bio fibers have low-cost with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements.

However, certain drawbacks such as incompatibility with the hydrophobic polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture limit the potential of bio-fibers to be used as reinforcement in polymers. Another important aspect is the thermal stability

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of these fibers. These fibers are lingo-cellulosic and consist of mainly lignin, hemi-cellulose, and cellulose. The cell walls of the fibers undergo pyrolysis with increasing processing temperature and contribute to char formation. These charred layers help to insulate the lingo- cellulosic from further thermal degradation. Since most thermoplastics are processed at high temperatures, the thermal stability of the fibers at processing temperatures is important. Thus the key issues in development of bio reinforced composites are (i) Thermal stability of the fibers, (ii) Surface adhesion characteristics of the fibers, and (iii) Dispersion of the fibers in the case of thermoplastic composites.

1. 9Types of Bio Fibers

Bio fibers are grouped into three types: seed hair, bast fibers, and leaf fibers, depending upon the source. Some examples are cotton (seed hairs), ramie, jute, and flax (bast fibers), and sisal and abaca (leaf fibers). Of these fibers, jute, ramie, flax, and sisal are the most commonly used fibers for polymer composites. On the basis of the source which they are derived from bio fibers can also be grouped as: a) Fibers obtained from plant/vegetable. (cellulose: sisal, jute, abaca, bagasse) b) BFibers obtained from mineral. (minerals: asbestos) c) Fibers derived from animal species.(sheep wool, goat hair, cashmere, rabbit hair, angora fiber, horse hair, human hair) d) Fibers from bird / aqueous species.(feather, sea snels etc.)

Numerous reports are available on the bio fiber composites. The research works on development of bio/bio-fiber reinforced polymer composites have <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

been extensively reviewed also. Many researchers have been conducted to study the mechanical properties, especially interfacial performances of the composites based on bio fibers due to the poor interfacial bonding between the hydrophilic bio fibers such as sisal, jute and palm fibers and the hydrophobic polymer matrices.

1. 10 Mechanical Properties of Bio Fibers

As can be seen from Table 1, the tensile strength of glass fibers is substantially higher than that of bio fibers even though the modulus is of the same order. However, when the specific modulus of bio fibers (modulus/specific gravity) is considered, the bio fibers show values that are comparable to or better than those of glass fibers. These higher specific properties are one of the major advantages of using bio fiber composites for applications wherein the desired properties also include weight reduction.

Table 1. 1 Mechanical Properties of Bio Fibers (Source Ref. 9).

1. 11 Matrix Resins

Thermosets versus Thermoplastics

Nowadays both thermoplastic and thermosetting resins are used as matrices for composites. Each type exhibits particular advantages and disadvantages with respect to processability and service performance, as illustrated in Table 2. 6. Although a wide range of different chemistries exists within each type, some general features can be distinguished, which have determined their area of application. Table 2. 6 Property/process characteristics for thermoplastic and thermosetting matrix systems-

Some of the basic properties of selected thermoset and thermoplastic resins are shown in Table 2. 7 and Table 2. 8, respectively.

Table 2. 7 Typical unfilled thermosetting resin properties (Mazumdar, 2002, p. 48).

In general the crosslinked structure of thermosetting polymers provides potential for higher stiffness and service temperatures than thermoplastics. The upper limit of service temperature for advanced composites is most often determined by the glass transition temperature.

On the other hand, toughness and elongation to break may be considerably for thermoplastic resins. This may be a particular advantage in applications where impact strength is a major requirement. Most high-performance thermoplastics offer outstanding interlaminar fracture toughness and acceptable post-impact compression response. This feature of thermoplastic materials has been the major reason for their increased use in composite structures. Table 2. 8 Typical unfilled thermoplastic resin properties (Mazumdar, 2002, p. 53).

From a processing viewpoint, the high melt viscosities of thermoplastics generally create considerable difficulties during fiber wet-out and impregnation. Thus, thermoplastic-based composites generally require higher processing temperatures and pressures to ensure sufficient flow during the final forming process. The higher processing temperatures and pressures needed for the forming of thermoplastic-based composites generally impose stricter requirements on the processing equipment, and more advanced engineering is needed for tool construction. The higher

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processing temperatures may also induce considerable difficulties in mismatch of thermal contraction between the matrix and fibers during the processing cycle.

The longer relaxation times for thermosetting materials may be a disadvantage, due to a reduced ability to relax process-induced internal stresses. In anisotropic composites in particular, the potential of the polymer to relax internal stress fields is important for the elimination of process-induced defects. Such defects, in the form of voids, microcracking, fiber buckling, warpage, and residual stresses may diminish the durability and long-term performance of the composite.

Thermoplastic-based composites offer potential for lower conversion costs from intermediate material forms into final end-use parts by process automation. Furthermore, thermoplastics also offer the advantage of having almost indefinite storage life, which facilitates the logistics of the manufacturing procedure.

Finally, thermoplastics may be post-formed and/or reprocessed by the reapplication of heat and pressure, which gives a potential for recyclability. The increased awareness, in these last years, about material Recyclability has brought about a heightened interest in thermoplastic matrix composites, especially in large volume areas such as the automobile industry.

1. 12Thesis Outline

The remainder of this thesis is organized as follows:

Chapter 2

Includes a literature review designed to provide a summary of the base of knowledge already available involving the issues of interest.

Chapter 3:

Includes a detailed description of the raw materials, test procedures, and design of experiments methodology.

Chapter 4:

Results and discussion

Section: 1 Physico – mechanical properties of composites.

Chapter 5:

Provides the thesis summary conclusions and recommendation for future work.

Chapter 2

Literature Review

Chapter 2

Literature Review

During the last decades, particulates with fibers and fillers features so called reinforce plastics are utilized to improve the physical and mechanical properties of polymers and composites. Among the natural, inorganic and organic fibers and fillers have been widely studied. In this study, keratin fiber (human hair) use as organic natural fibers. Both filler and fiber are low cost, higher thermal stability, excellent mechanical properties and abundance

provoked us to use these with plastics material. Natural fibers have received <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

much attention as reinforcing materials for polymers because of their potentially high aspect ratio and unique intercalation / exfoliation characteristics. Keratin fiber based composites has the lower density and good mechanical properties as compare to material. Keratin fiber enhance mechanical properties like impact, tensile, fracture etc, and reduce density.

2. 1Natural Bio-Fiber Reinforced Composites

Synthetic fibers such as glass, nylon, carbon, Kevlar and boron are generally used to make composite materials for specific purposes even though they are expensive and are non-renewable resources. This is because of their very high specific strength properties which do not deteriorate appreciably with time. On the other hand, there is a growing interest in the development of new materials which enhance optimal utilization of natural resources, and particularly, of renewable resources. The natural fibers like Keratin, cotton, jute and sisal have also attracted the attention of scientists and technologists for applications in consumer goods, low cost housing and civil structures where the prohibitive cost of synthetic fibers restricts their use. These natural fiber composites possess characteristic properties such as high electrical and impact resistance, good thermal and acoustic insulating properties and high work of fracture in addition to specific strengths comparable to synthetic fiber reinforced polymer composites. Accordingly, manufacturing of high-performance engineering materials from renewable resources has been pursued by researchers across the world owing to renewable raw materials are environmentally sound and do not cause health problem.

It is known that natural fibers are non-uniform with irregular cross sections which make their structures quite unique and much different with man-made fibers such as glass fibers, carbon fibers etc. Saheb and Jog have presented a very elaborate and extensive review on the reported work on natural fiber reinforced composites with special reference to the type of fibers, matrix polymers, treatment of fibers and fiber-matrix interface. Many researchers have been conducted to study the mechanical properties.

The matrix phase plays a crucial role in the performance of polymer composites. Both thermosets and thermoplastics are attractive as matrix materials for composites. In thermoset composites, formulation is complex because a large number of components are involved such as base resin, curing agents, catalysts, flowing agents, and hardeners. These composite materials are chemically cured to a highly cross-linked, three-dimensional network structure. These cross-linked structures are highly solvent resistant, tough, and creep resistant. The fiber loading can be as high as 80% and because of the alignment of fibers; the enhancement in the properties is remarkable. Thermoplastics offer many advantages over thermoset polymers. One of the advantages of thermoplastic matrix composites is their low processing costs. Another is design flexibility and ease of molding complex parts. Simple methods such as extrusion and injection molding are used for processing of these composites.

In thermoplastics most of the work reported so far deals with polymers such as polyethylene, polypropylene, polystyrene, and poly (vinyl chloride). This is mainly because the processing temperature is restricted to temperatures below 200°C to avoid thermal degradation of the natural fibers. For <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

thermoplastic composites, the dispersion of the fibers in the composites is also an important parameter to achieve consistency in the product. Thermoplastic composites are flexible and tough and exhibit good mechanical properties. However, the percentage of loading is limited by the process ability of the composite. The fiber orientation in the composites is random and accordingly the property modification is not as high as is observed in thermoset composites. Properties of the fibers, the aspect ratio of the fibers, and the fiber-matrix interface govern the properties of the composites. The surface adhesion between the fiber and the polymer plays an important role in the transmission of stress from matrix to the fiber and thus contributes toward the performance of the composite. Another important aspect is the thermal stability of these fibers. Since most thermoplastics are processed at high temperatures, the thermal stability of the fibers at processing temperatures is important. Thus the key issues in development of natural reinforced composites are (i) thermal stability of the fibers,

(ii) surface adhesion characteristics of the fibers,

(iii) dispersion of the fibers in the case of thermoplastic composite.

2. 2Keratin fiber

Hair is composed of proteins, lipids, water, and small amounts of trace elements. All proteins in animal and human bodies are built from permutations of amino acid molecules in a polypeptide string. The polypeptide chains of protein keratin are organized into filaments in hair cells. Hair is one of the most difficult proteins to digest or solubilize. Among the most common dissolving procedures for hair are acidic, alkaline, and <https://assignbuster.com/effect-of-reinforcement-of-keratin-fiber-on-hdpe-essay-sample/>

enzymatic hydrolysis. For the analysis of hair, the solid samples are transferred by solubilization via digestion into a liquid phase. Small molecular solvents and molecules with hydrophobic groups appear to have higher affinity for hair. A good solvent attacks the disulfide bonds between cystine molecules and hydrates the hair shaft. Consequently, the hair becomes a jelly-like mass.

2. Structure and Properties

Hair is a biological material consisting of polypeptide chains of keratin arranged into filaments. In most mammals, hair increases the sensitivity of the skin surface and forms an insulating and protective coat. Hair reduces heat loss from the body and often provides camouflage. For humans, hair is important only for personal adornment and display. In lower animals (e. g., insects), hairs (whiskers) have a sensory function. Some stems, leaves, and plants also possess hairs on their roots. Hair is a complex tissue and grows from the hair follicle embedded in the inner layer (dermis) in the skin where the germination center is formed by matrix cells that are in active build-up to layers of the hair shaft, including the cuticle, cortex, and medulla. The cortex forms the bulk of the hair shaft and is located immediately beneath the cuticle. The medulla is the innermost region of hair and consists of scattered cells and hollow space. Human hair is not homogeneous. In the outer layers of hair, the surface composition may vary rapidly.