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Production & Stabilization of Silver Nanoparticles on Polyamide Nylon and its Antibacterial activity

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Abstract: Incredibly significant events occurred in 1930 that have affected people's lives ever since. The invention of nylon was a significant event that altered how people dress and go about their daily lives. Even more job prospects and advancements at work were made possible by it throughout time. The first synthetic material, nylon, was created in 1934 by a group of DuPont researchers under the direction of Dr. Wallace Hume Carothers (Adams 21). When they pulled an elastic string from plastic and created nylon, they were looking for a synthetic alternative to silk. Compared to other materials currently in use, this new creation offered many more superior features and/or capabilities. Nylons are the most recognized for their ability to be dyed, for not being damaged by most house hold cleaners or greases and oils, for drying quickly, and most importantly, for having a silk like appearance (The world Book).

Nylon has a higher tensile strength than cotton, rayon, silk, and wool (Encarta).Additionally, they include qualities like flexibility, cleaning ease,The controlled reduction of Ag+ ions with sodium borohydride at room temperature produced silver nanoparticles (NPs). Ag nanoparticles were added to Nylon 6,6 by trapping Ag+ ions in the polymer network and then reducing them. Scanning microelectronic microscopy (SEM) was used to characterize the nanocomposite. Bacillus coli communis (Escherichia) was used in vitro antibacterial experiments to ascertain the substance's antibacterial capacity. The present work studies the effect of silver nanoparticles in the range of 1–100 nm on Gram-negative bacteria using high angle annular dark field (HAADF) scanning transmission electron microscopy (STEM).

Keywords: Silver nanoparticles, Nylon 6, 6, Antibacterial effect, Bacillus coli communis (Escherichia)

1. Introduction

Since many years ago, antimicrobial substances such as elemental silver and silver salts have been employed in both curative and preventive healthcare. Antimicrobial silver ions and silver complexes typically alter microbial activity [1, 2].

The different silver complexes are intriguing because the kind of ligands coupled to the silver ion, such as the silver imidazolate, can alter the antibacterial activity and other desired features. The silver imidazolate triphenyl phosphine adduct, however, shows little antibacterial action. There may be limitations on the usage of protection since some kinds of silver ions may be harmful to the environment. metal oxide and silver nanoparticles seem to be making a comeback in a variety of biomedical applications, according to recent cutting-edge research on metal nanoparticles.

Silver nanoparticles have certain advantages over silver salts because they are more stable against dissolution and diffusion to the surface of items to be protected. [13]. Antibacterial activity against Bacillus coli communis (Escherich) was demonstrated by nanometer-sized silver particles created by inert gas condensation or co-condensation procedures. By adding the nanoparticles to a medium having B. coli, the antibacterial nature of the particles was examined, and it was discovered that they demonstrated an antibacterial impact at low concentrations. Additionally, a correlation between the antibacterial qualities and the overall surface area of the nanoparticles was found. In the antibacterial activity tests, smaller particles with more surface area performed better. Ag's strong affinity for sulfur or phosphorus is thought to be the key to its antibacterial properties.

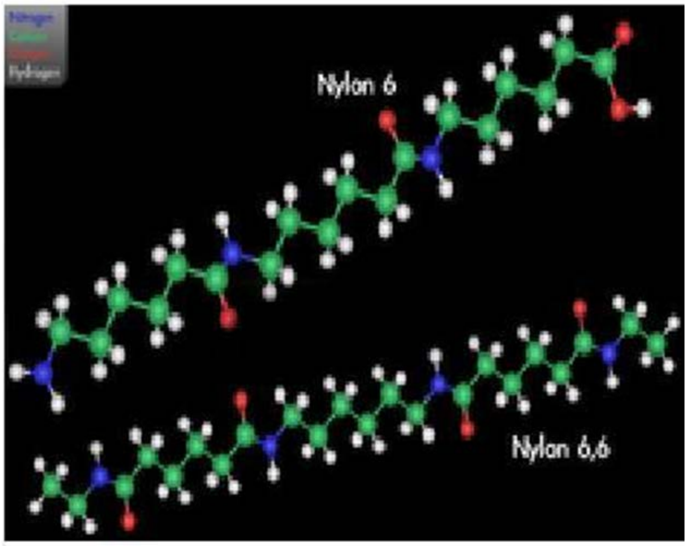

Fig 1. A synthetic nylon6,6 fabric

The quantity of phosphorus and sulfur in the cell membrane causes Ag nanoparticles interact with sulfur-containing proteins either inside or outside of the cell membrane, which affects the cell's ability to survive. Ag nanoparticles (AgO) can bind with phosphorous moiety in DNA to prevent DNA replication or with proteins containing sulfur to prevent enzyme activity [6–10]. Polyurethane foams can be coated with silver nanoparticles in a variety of ways. The nanoparticles in this material can be washed numerous times without losing any of them. When the input water had a bacterial load of 105 to 106 CFU/ml, the material's performance as an antibacterial water filter was examined, and no bacterium (B. coli) was found in the output water. In this investigation, E. coli was used as a fecal contamination marker. Various studies conducted to explore the bactericidal effect of supports like polypropylene and textile textiles [11–12]. Some of the most significant commercially produced fibers are nylons. Clothing uses up a lot of the nylon that is produced. However, nylon is not limited to textiles. Nylon 6,6 is one of the most significant varieties of nylon and is produced through polycondensation. These characteristics make it possible to incorporate silver nanoparticles into a variety of matrices, including polymer networks, textiles, and materials for wound dressings. To manufacture Ag-coated matrices, the majority of procedures call for many steps and complicated reagents [5]. In this study, interfacial synthesis was used to generate nylon 6,6, which was then loaded with silver nanoparticles to create an Ag/nylon nanocomposite and its antibacterial effects on B. coli were assessed.

2. Experimental:

2.1 Materials and apparatus:

All of the chemicals and tools were bought from Merck. All synthesis and measurements used triple-distilled water. Images from a scanning electron microscope (SEM) were captured using a S-4700 (Delhi, India) that was running at a 15 kV acceleration voltage.

2.2 Preparation of nylon 6, 6

Nylon 6,6 was prepaqred by combining 10.5 mL of 0.50 weight percent adipoyl chloride in cyclohexane and 10.5 mL of 0.50 weight percent hexamethylene diamine in water. The polymer was then removed from the two-phase interface.

2.3 Preparation of Silver loaded nylon 6, 6

Distilled water was used to balance a dry, pre-weighed piece of nylon 6,6 fabric for 24 hours. The cloth was then immersed for 24 hours in an aqueous solution of $AgNO_3$ made by dissolving 10.5 mg of silver nitrate in 20 mL of distilled water. Then, fabric was submerged in a 0.7 mM sodium borohydride solution for 24 hours at 300C to convert the Silver ions present in the fabric to silver nanoparticles. The production of Ag nanoparticles within the polymer network was revealed by the Nylon 6,6 fabric's subsequent dark brown color. The fabric was then placed in a dust-free chamber and heated to 400°C for 15 seconds while gaining consistent weight.

2.4 Chemistry of Nylon:

Nylons are condensation copolymers that produce peptide linkages at both ends of each monomer, a procedure similar to that of polypeptide biopolymers, by reacting an equimolar combination of diamine and a dicarboxylic acid. Included are the chemical elements carbon, hydrogen, nitrogen, and oxygen. The diamine and diacid are the monomers that contribute the most carbons, as shown by the numerical suffix. Nylon 6-6 refers to the fact that the diacid (adipic acid; IUPAC name: hexane-1,6-dicarboxylic acid) and the diamine (hexamethylene diamine; IUPAC name: 1, 6-diaminohexane) each contribute 6 carbons to the polymer chain. is the most popular type. One of each monomer makes up the "repeating unit" in conventional copolymers like polyesters and polyurethanes, where they alternate in the chain. Each monomer in this copolymer has the same reactive group on both ends, hence the direction of the amide bond between each monomer reverses, in contrast to natural polyamide proteins, which have general directionality the N terminal is C terminal. In the lab, adipoyl chloride can be used to create nylon 6-6 in place of adipic acid. The optimum ratios are difficult to establish, and any deviations could cause the chain to terminate at molecular weights below the desired 10,000 daltons (u). This problem can be solved at room temperature by exact 1:1 neutralization of the base and acid, resulting in a crystalline, solid "nylon salt". The salt interacts to produce nylon polymer when heated to 285 °C. Acetic acid is given to the polymer during polymer elongation to react with a free amine end group in order to limit the molecular weight in order to prevent this. Above 20,000 daltons, the chains cannot be spun into yarn, therefore this is a problem. In reality, the monomers are frequently mixed together in a water solution, notably for 6,6. Due to DuPont's patent on nylon 6, other businesses— especially the German BASF—produced homo polymer nylon 6, also known as poly caprolactam, which was synthesized by ring-opening polymerization inspite of condensation polymerization (or, alternately, by polymerizing aminocaproic acid).

Even before nylon 6,6, Carothers explored nylon 5,10, which is formed of pentamethylene diamine and sebacic acid. Nylon 5,10 has superior characteristics, but it is more expensive to produce. A copolymer composed of a 6C diamine and a 12C diacid is known as "nylon 6,12" (N-6,12) or "PA-6,12". For N-5, N-10, N-12, N-6, etc., see also. Items made from copolymerized dicarboxylic acid/diamine that don't use the aforementioned monomers type of nylon. The way polyamides are made would seem to limit nylon to unbranched, straight chains. However, condensation of polyamines with three or more amino groups and dicarboxylic acids can result in "star" branched nylon.

The general reaction is:

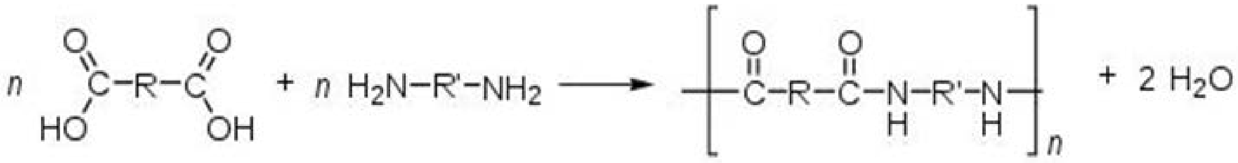

Fig. 2 Formation of Kevlar

The formation of nylon involves the release of a water molecule. The R and R' groups in the monomers control its characteristics. To obtain the number the diacid provides to the chain, one must additionally take into account the two carboxyl carbons in the diacid. In nylon 6,6, R = 4C and R' = 6C alkanes. Both R and R' are benzene rings in Kevlar.

2.5 Concepts of nylon production:

In the first approach, two molecules with amine (NH2) groups on each end are combined with two molecules with acid (COOH) groups on each end. This method results in nylon 6,6 by using hexamethylene diamine with six carbon atoms and adipic acid. The second approach entails polymerizing a substance that has an acid and an amine at one end to produce a chain of repeating (-NH-[CH2]n-CO-)x units. In other words, caprolactam, a compound with six carbons, is used to make nylon 6. Nylon 6 is the name given in this equation if n=5 (it may alternatively be referred to as polymer).

The main features of nylon 6,6 have:

- Better resilience to sunshine and improved weathering qualities
- Superior colorfastness
- Elevated melting point (256 °C)
- Softer "Hand"
- High abrasion resistance

Contrarily, nylon 6 is simple to dye, more easily fades, and has better flexibility and elastic rebound. It also has a higher resistance to impact and absorbs moisture very quickly. Characteristics:

- Varying sheen: Nylon can have a high sheen, a medium sheen, or a drab sheen.
- Durability: Seatbelts, tire cables, ballistic fabric, and other items are made from its high tenacity fibers.

2.6 Bulk properties

Thermoplastics like nylon are amorphous solids above their melting temperatures, Tm. Amorphous areas and lamellar crystal zones alternate below Tm.[1] Elastic behavior is contributed by the amorphous portions, whereas power and stiffness are contributed by the crystalline sections. Due to the polar nature of the imide groups, nylon generates many hydrogen bonds between neighboring strands. Because of the nylon's regular and symmetrical backbone, which is especially true when all of the present imide bonds are trans, nylons frequently have high limpid and form superior fibers. The type of nylon and the specifics of its production affect how crystalline the material is. It seems that it can never be solidified from a melt as a fully amorphous state. Multiple parallel strands of nylon 6,6 can coordinately separate exactly 6 and 4 carbons from their surrounding peptide bonds for significant distances, allowing the carbonyl oxygen's and amide hydrogen atoms to establish inter chain hydrogen connections repeatedly and uninterruptedly. Thus, parallel (but not antiparallel) strands can take part in lengthy, unbroken, multi-chain -pleated sheets, a robust and durable supermolecular structure akin to the -keratins in feathers and the natural silk fibroin. (Proteins only have one amino acid -carbon between each subsequent -CO-NH- group.) Nylon 6 will produce mixed directionality, unbroken H-bonded sheets, however the -sheet wrinkling is a little different. After being subjected to cold drawing, the material gains more tensile strength as the fibers further align, becoming more crystalline.[2] In reality, heated rolls spinning quickly are most frequently used to pull nylon strands.

Due to shearing forces during production, block nylon has a tendency to be less crystalline, with the exception of at the surfaces. Although nylon is clear and colorless, or milky, it may be colored readily. Nylon rope and cord with several strands are slick and prone to unraveling. To avoid this, the ends can be heated using an electrode or flame to melt and fuse them. Polyamide having a good electrical insulating property when it is dry. Polyamide is absorbent though. Several characteristics of the substance, including its electrical resistance, will alter as a result of water absorption. Wool or cotton are more absorbent than nylon.

3. Historical uses

At the starting months of World War II, the people and businesses put a lot of effort into figuring out a way to use nylon in parachutes instead of Asian silk and hemp. Even the manufacturing of high-grade paper for US money employed it. More over 80% of the fibers utilized and produced at the start of the war were cotton, with wool fibers making up the remaining 20%. Cotton had decreased in August1945, and synthetic fibers accumulate a 25% market share. Some of the nylon-based terpolymers are frequently utilized in packaging. Sausage sheaths and meat wrappings have both been made of nylon.

3.1 Use in composites

The polymer has a higher density than pure nylon and can be utilized as the component that acts as the matrix in composite materials that contain glass or carbon fiber for reinforcement. Such composites made of thermoplastic, which contain 25% glass fiber, are often employed in intake manifolds and other engine-related auto parts, where their excellent heat resistance makes them competitive alternatives to metals.

4. Hydrolysis and degradation

All nylons can hydrolyze, especially when exposed to strong acids, which is effectively the opposite of the artificial reaction depicted. The weight of nylon things that have been attacked lowers swiftly, and fissures appear at the afflicted areas soon. The nylons' lower members, such nylon 6, are more affected than other members of Nylon family. As a result, nylon components cannot be employed in sulfuric acid-containing environments, such as the electrolyte in accumulator storage battery. So water at elevated temperature can also disintegrate the polymer, the polymer must be dry before molding to avoid hydrolysis in the barrel machine. The reaction is the following:

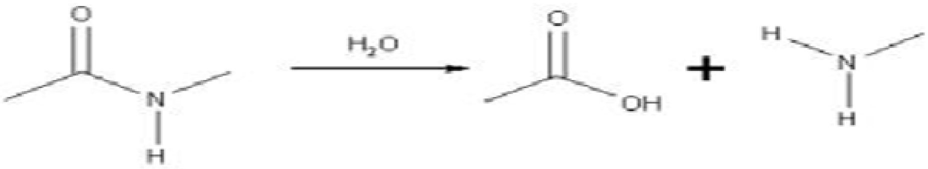

Fig. 3 Hydrolysis of Nylons

5. Incineration and recycling

Various nylons burn badly and discharge harmful smokewhich contain methanonitrile. Since nylons are quite high priced to ignite in order to recoup the considerable energy required to make them, the greater part of nylons at the end in soil where they slowly decompose. Although it is done on a much smaller scale, some recycling of nylon is done, typically producing pellets for reuse in the industry.

6. Results and discussion

In Fig. 1, a synthetic nylon6,6 fabric with a smooth surface that is prepared to stabilize Ag particles is depicted using a scanning electron microscope (SEM).

Fig. 4 SEM image of Ag/ Nylon 6,6 nanocomposites

7. Antibacterial test for Ag/nylon 6,6 nanocomposites

B. coli was used to assess the fabric's antibacterial properties. The Ag-loaded fabric was cut into discs of 6 mm in diameter and examined using the modified agar diffusion assay (disc test) to determine the antibacterial activity's qualitative level. After being incubated at 30 0C for 2 hours, the plates were checked for any potential clear zones. A clean zone surrounding the circular disc on the plate medium indicated that the microbial species had been inhibited.

8. **Conclusion**

In conclusion, the process of fabric forming described in this paper produced strong permanent silver-nano coated fabric in a way that was both simple and economical, with total control over the quantity of silver loading on the fabric. By carefully assessing the bactericidal effect on E. coli and an antibiotic-resistant strain, we investigated the possibility of this functionalized cloth as an antiseptic bandage. In particular, the use of biomaterials for wound dressings necessitates extensive multidisciplinary research combining scientists, biotechnologists, and physicians. Interaction, coordination, and cooperation between wound care specialists, allied teams, and governing bodies

The development of new materials on antimicrobial stewardship in 2019–12–2540 11–16 will contribute to the advancement of the battle against antibiotic-resistant infections in wound care.

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