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Synthetic Textiles for Fashion: Polyester, Nylon and Kevlar

While many would think of Chanel or Valentino as major centers in the production of fashion, Du Pont Chemical Company has revolutionized fashion more than any other organization. Because the well-known polymers Polyester, Nylon and Kevlar were created within its walls, DuPont has had a major influence on the world of fashion in addition to other significant industries that are concerned with military needs, technology, automobile, home appliances and a variety of modern technological products.

Polyester's creation dates back to the late 1920's; it is attributed to DuPont's William Carothers and his research group. The development began when Carothers started to investigate the chemistry of reacting aliphatic diacids (a hydrocarbon with two acid groups) with diols (a hydrocarbon with two alcohol groups) in hopes of achieving a fibrous material. Much to their discontent, initially their reactions only produced syrup-like mixtures. By exploring a variety of diols and diacids, they finally achieved a useful polyester. [1.]

Carothers used the concept of "driving" an equilibrium reaction, based on Le Chatelier's principle, to remove water from the diol and diacid reactants; thus, "driving" the reaction towards ester formation as seen in Figure 1.

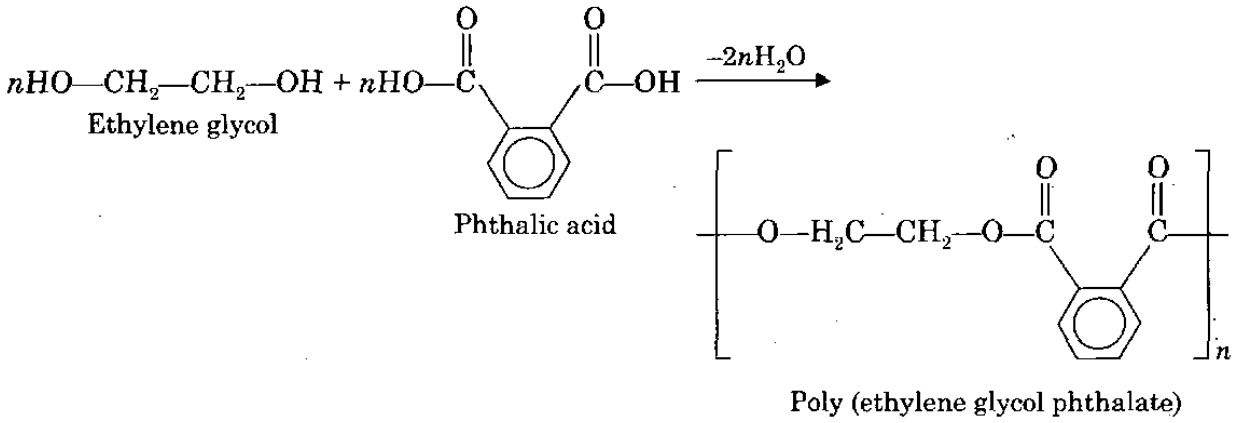

Figure 1: Carothers' condensation reaction between diol and diacid

Removal of water from the system was a difficult process; to solve that problem, the researchers had to develop a "molecular still," where in they heated the mixture and subsequently applied a vacuum along with a "cold finger" to condense the evaporated water. After much painstaking effort, the polymer chains achieved had less than 100 repeat units.[1] By 1931, DuPont attained patents on this incipient polyester form. While DuPont had created polyester, the company did not commercialize their polyesters at that time because the molecular weight was too low. It was in the 1940's that an English company, Imperial Chemical Industries, developed the initial practical polyester by reacting ethylene glycol and teraphthalic acid to form polyethylene terephthalate as seen in Figure 2 with "n" indicating the polymerized repeating $C_{10}H_8O_4$ unit. DuPont, however, bought the rights to this product and subsequently commercialized their Dacron polyester nearly ten years later.[2.]

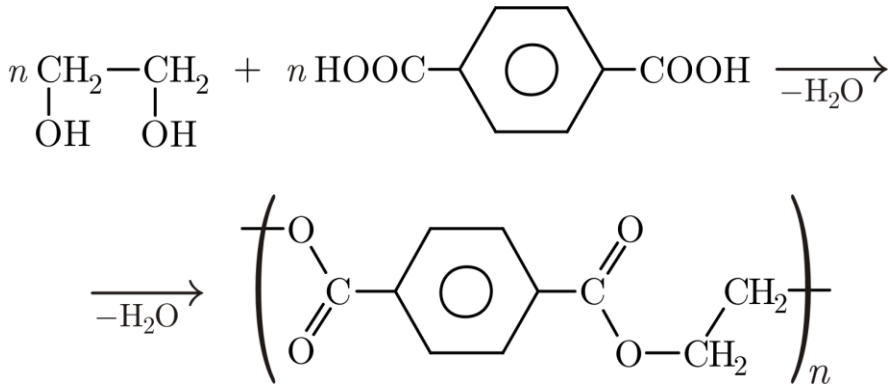

Figure 2: Polyethylene terephthalate synthesis

Today, there are many applications of polyester. Polyester fibers are very strong, stretch/shrink resistant, wrinkle resistant, and resistant to most chemicals. In the world of fashion in particular, polyesters were especially popular in the mid 1900's as petroleum, the source of polyesters was inexpensive and plentiful. However, since the 50's, polyester's name in fashion was marred, particularly with the advent of the cheap polyester suit, that was disliked because it was hot and uncomfortable. Currently, polyester maintains its popularity in clothing items like underwear and pajamas; however, more recently it has reemerged in Paris *haute couture,* or high fashion, as designers have seen the benefits and durability of polyester in creating geometric, ornate designs. 2011's Paris fashion week, in fact, featured polyester in designs by Lanvin's Alber Elbaz, Nina Ricci's Olivier Theyskens, and Narciso Rodriguez. It is said that new improvents in polyester have made the material "lighter, thinner and more delicate. Mr. Elbaz, who got a standing ovation for a series of $5,800 polyester evening gowns at his runway show last fall, said the texture of the new polyester was like cream. 'It was so light,' he said, as he rubbed an imaginary piece of cloth between his fingers."[9] Polyesters can also be found in home furnishings such as carpets, drapes, curtains as well as such items as hoses, ropes, nets.[3]

The Arrival of Nylon:

DuPont had initially put polyester on the backburner; the company decided instead to concentrate on a product they saw as far more promising: nylon. During the trials developing polyester, Carothers decided to refocus his energies on amides, a derivative of ammonia. Carothers discovered a particularly durable polyamide fiber. Nylon was created as a condensation copolymer similar to polyester using equal proportions of diamine and dicarboxylic acid (see Figure 3). DuPont patented nylon 6,6, a name that implied the number of carbons supplied by the diamine group and by the dicarboxylic acid. [4]

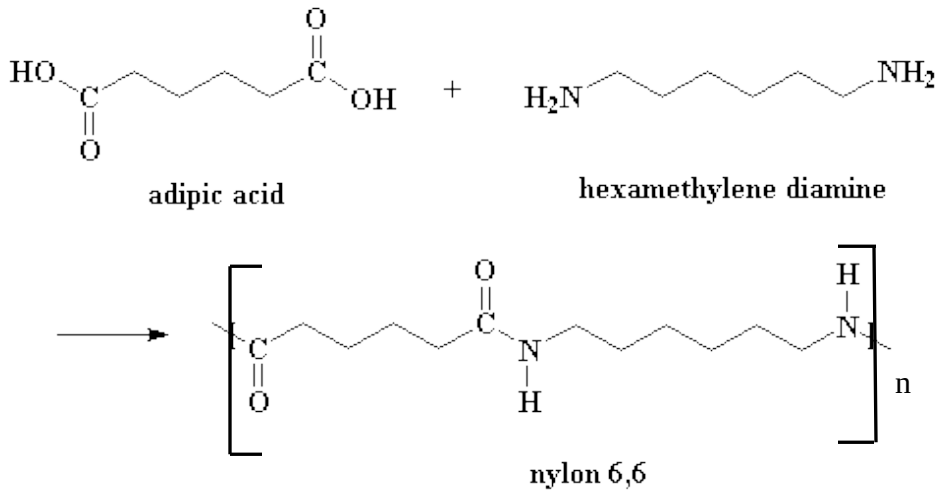

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Figure 3: Synthesis of Nylon 6,6

Du Pont soon proceeded to market this new synthetic fiber to women as hosiery. Commercial production began in 1939 and was not trademarked, because DuPont wanted nylon to become synonymous with "stockings." "When the nylon stockings were first offered for sale in New York City, on May 15, 1940, over four million pairs were sold in the first few hours. [5.]

Nylon proved revolutionary and grew to become the inexpensive substitute for silk, thus making silk stockings obsolete. Nylon was met with such popularity that DuPont had to build a

second nylon plant to meet the growing demand. It was truly with nylon that the synthetic textile revolution began. [5.]

Nylon was famous not only for hosiery but also during WWII when nylon proved vital for national defense: it was used in parachutes and B-29 bomber tires because of nylon fiber's durability. Nylon would later be used in carpeting and belting in truck/automobile tires. Some chemical drawbacks of Nylon; however, have arisen from the polar units in the Nylon molecule. While these polar units give Nylon its silk-like feel as well as its durability (resulting from hydrogen bonding), as many odors and liquids are polar, Nylon also tends to attract and absorb odors and also is prone to stain quite easily.[2].

Kevlar, a fiber made for durability:

More recently, DuPont's success was once again celebrated with Stephanie Kwolek's creation of Kevlar, "a fiber five times stronger ounce for ounce than steel, but about half the density of fiberglass." Similar to nylon, Kevlar is derived from polyaromatic amides and is similarly synthesized in a condensation reaction from monomers 1,4-phenylene-diamine and terephthaloyl chloride as seen in Figure 4.

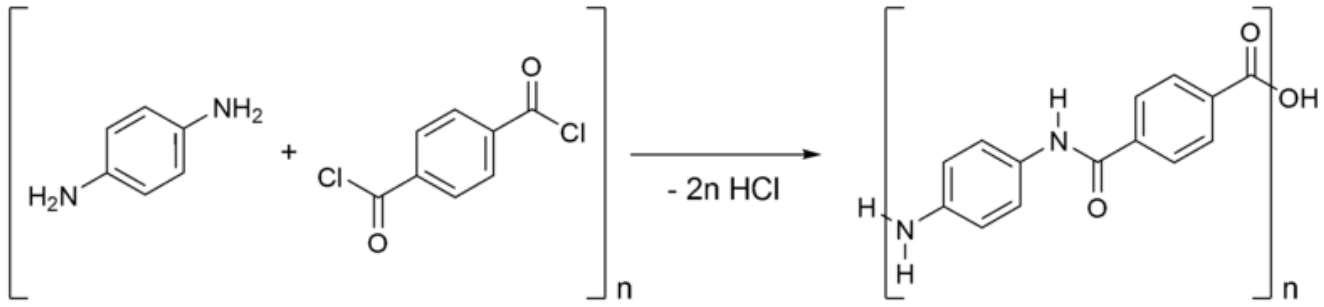

Figure 4: Kevlar synthesis reaction

Kevlar has unusual strength due to its crystallinity that is enhanced by "extruding the molten polymer solution through small holes." [7] Kevlar's strength is attributed to its intermolecular forces of attraction due to its polar groups and hydrogen bonding as can be seen by Kevlar's molecular structure in Figure 5. The aromatic groups provide a distinct regularity and symmetry to the overall structure; thus further enhancing Kevlar's durability. [7]

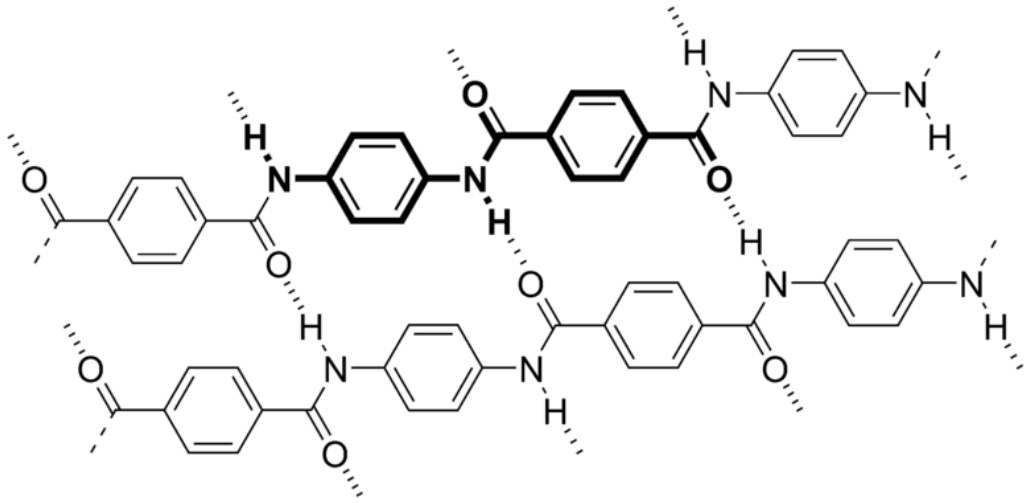

Figure 5: Molecular Structure of Kevlar (hydrogen bonding indicated by dotted lines)

Kevlar's exceptionally high tensile strength and low density make it appropriate for is most recognizable use today as the material for bullet proof vests; 6 mm of Kevlar can stop a 0.38 caliber bullet. To put this in context, about 95 percent of guns confiscated by U.S. police are less than 0.38 caliber. Based on this, the U.S. army has adopted Kevlar into a majority of soldier apparel/equipment.

"I was elated to have made this discovery," Stephanie says about the invention of Kevlar® "because most people work a lifetime, and they never do anything like this, something that saves human lives." [4.]

Kevlar has been adopted across a multitude of industries with products ranging from suspension bridge cables to sporting goods to personal electronics as well as products for military/law-enforcement purposes. While Kevlar presents its benefits in safety and practicality terms, Kevlar has become an integral part of many fashion designers' latest lines. During the emergence of polyesters and nylon, haute couture sought influence from science, technology and science fiction and thus such synthetic fibers, especially nylon and polyester were swiftly utilized by couturiers including Dior, Givenchy and Balmain. While for many decades nylon and polyester became "tacky," more recently science and technology-inspired fashion has reemerged, and so Kevlar has been spotted on runways of Paris designers, particularly with respect to motorcycle/biking attire.

DuPont has epitomized the potential of synthetic fibers has made their products relevant in our lives. Despite decreased popularity in fashion, it is predicted that over the next ten years, global demand for polyester will increase by 7 percent per annum, particularly led by strong growth in Asian markets. And as polyester fibers can replace cotton fibers, polyester and synthetic fibers reduce the threat of a shortage of natural fibers. However, petroleum based polyester has seen an increase in cost in correlation with the increasing price of crude oil. Nevertheless, synthetic fibers remain a popular choice; global output achieved a record 33 million tons in 2004.

Considering today's environmental awareness, DuPont is moving towards more environmentally friendly ways for making synthetic fibers. DuPont is also involved in the "sustainable fashion" movement, specifically in a process using "AirDye" Technology that eliminates the use of water in both dyeing and printing. This process decreases water

consumption and pollution. Despite negativities associated with synthetic fibers with respect to fashion and the environment, recent improvements in both the quality as well as the environmental impact of synthetic fibers provide a promising future for DuPont's creations.

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