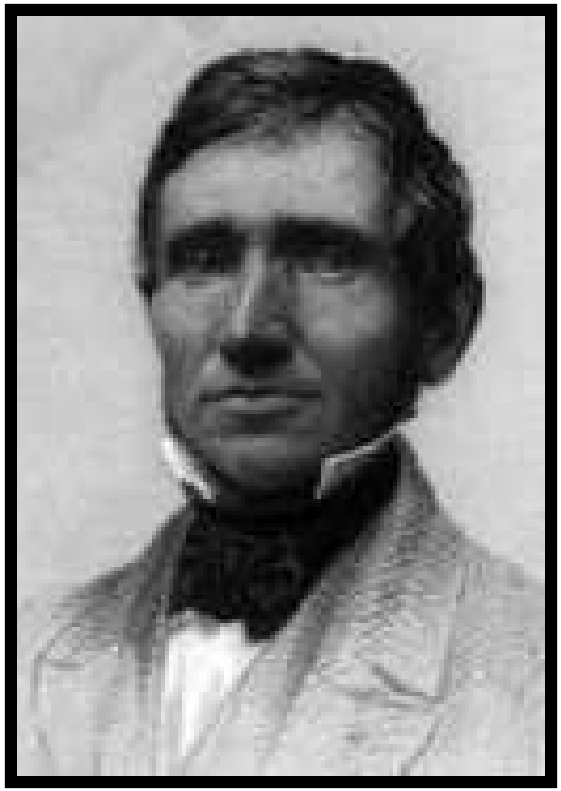
History of Plastics

Part 1: Injection Molding Curriculum

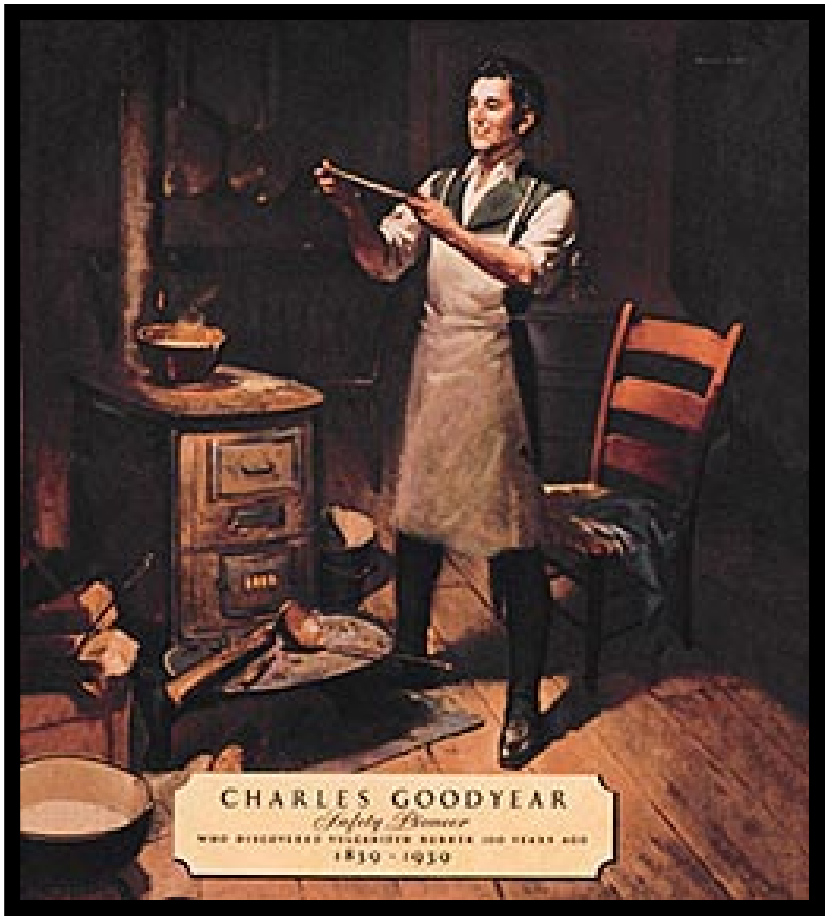
History Of Plastics Injection Molding

- Plastics are said to be the most *versatile* materials on earth. Almost all of the products we use in our daily lives contain plastics. This display chronicles some of the key discoveries, inventions, and people that have helped make the plastics industry what it is today.

- You will notice that many important developments related to plastics and rubber happened right here in Massachusetts, beginning with Charles Goodyear's 1839 discovery of the vulcanization process for natural rubber in nearby Woburn. Also note that UMass Lowell (formerly *Lowell Technological Institute*) was the very first university in the nation to offer a degree in Plastics Engineering. Take a few minutes and learn more about the "History of Plastics".

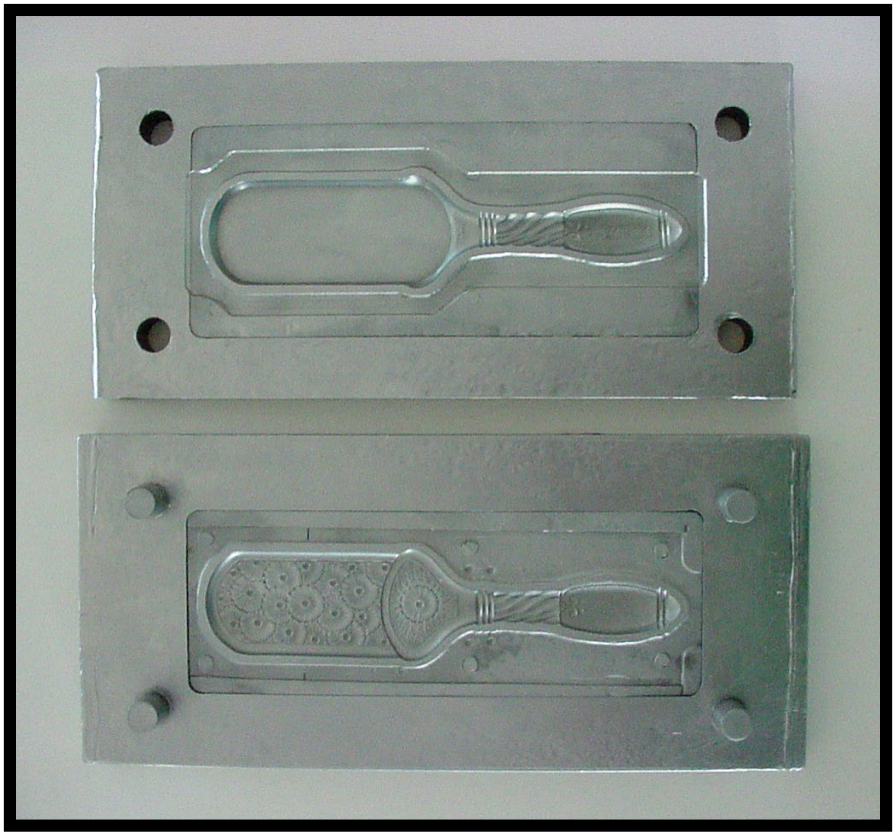


Charles Goodyear



Charles Goodyear spent most of his adult life trying to improve the properties of natural rubber. Working in Woburn, MA in 1839, Goodyear discovers that adding sulfur to natural rubber greatly enhances its elasticity and toughness. His “sulfurized” rubber, later known as “vulcanized” rubber, is still widely used today. While the Goodyear name is famous, Charles Goodyear never realized fortune from his invention.

Molded plastic mirror frames and a hand made compression mold. (*circa 1866*)



The mirror frames shown above are among the earliest molded “plastic” parts ever made. They were compression molded from a shellac based plastic molding compound known as *Florence Compound* which was developed in Florence, MA. Its inventor, Alfred Critchlow, founded the Pro Molding Corporation in 1847. Pro is thought to be the very first plastics molding company to be established in the United States.

Alexander Parkes

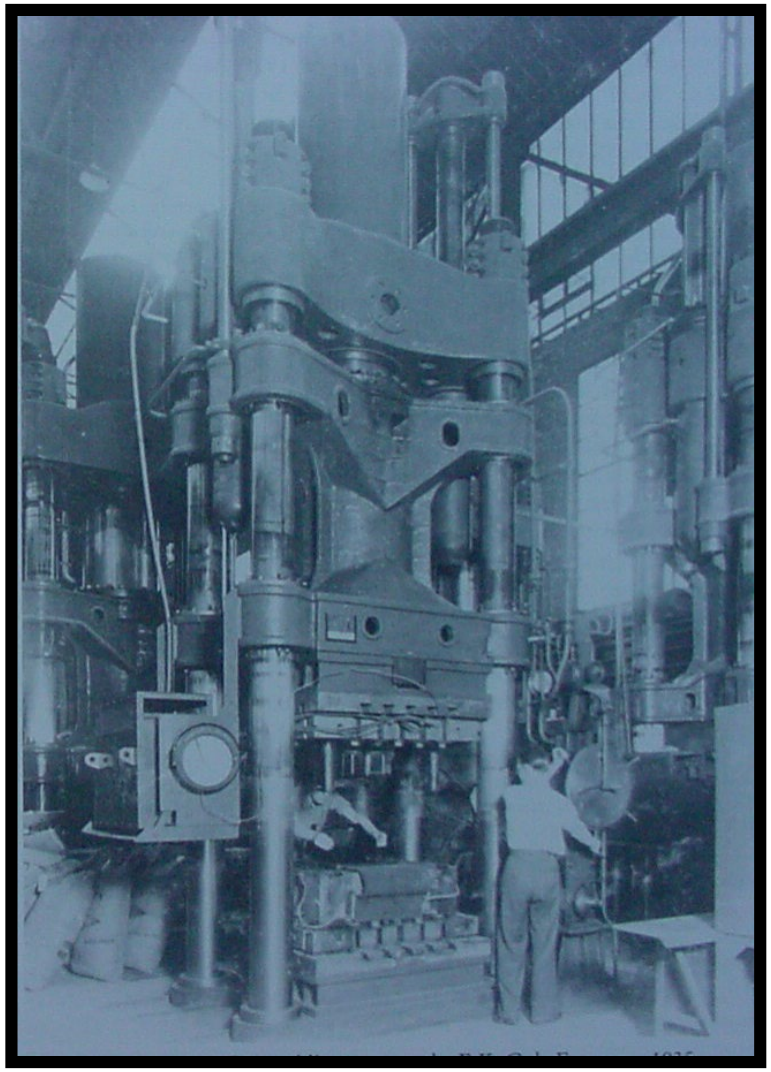
A new semi-synthetic plastic was unveiled by Alexander Parkes at the 1862 *Great International Exhibition* in London, England. This new material, which the public dubbed *Parkesine*, was an organic material consisting of cellulose nitrate and a solvent. *Parkesine* could be heated, formed, and it retained its shape when cooled. The material could be molded or carved into products such as buttons, combs, picture frames and knife handles. However, *Parkesine* was never commercialized due its relatively high cost compared to vulcanized rubber.

John Wesley Hyatt

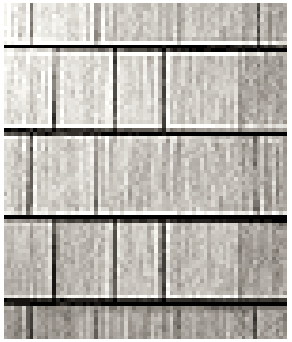
John Wesley Hyatt, a printer and inventor from Albany NY, blended nitrocellulose with camphor (sap from the laurel tree) to produce a durable, colorful, and moldable thermoplastic known as *celluloid* (also known as *Pyroxylin*) in 1868. *Celluloid* was the first commercially successful semi-synthetic plastic. It was used for products such as billiard balls, shirt collars, eyeglass frames and pen housings.

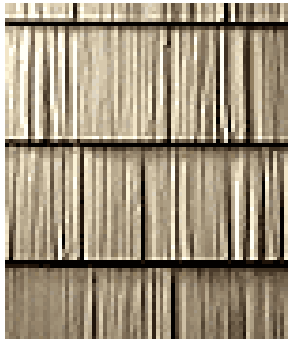
Dr. Leo H. Baekeland

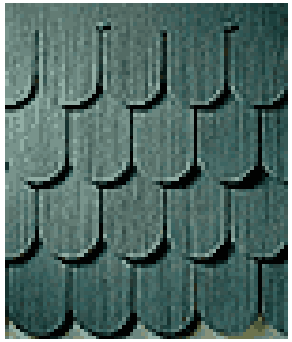
The first synthetic plastic was discovered in 1907 when a Belgian born chemist, Dr. Leo H. Baekeland, reacted phenol and formaldehyde under pressure using hexamethylenetetramine as a catalyst for the reaction. The result was a thermosetting “phenolic” plastic he named *Bakelite*. Compared to other plastics available at the time, such as *celluloid*, Baekeland’s thermosetting phenolic was more stable. Once molded, this new material would not burn or soften when reheated, or dissolve. This benefit made it stand out from the other plastics on the market. *Bakelite* was an instant commercial success. It was electrically resistant, chemically stable, heat resistant, rigid, moisture and weather resistant. It was very widely used for its electrical insulating capability. Baekeland sold the rights to his invention to the Eastman Kodak Company that first used it for camera bodies. It is also interesting to note that J.W. Hyatt, inventor of *celluloid* and founder of the Hyatt-Burroughs Billiard Ball Company, personally ordered his company to stop using *celluloid* and substitute *Bakelite* for their billiard balls due to its superior performance.



Most early “thermoset” plastic parts were produced by compression or transfer molding. These molded phenolic *Ekco* radio housings are being deflashed after being compression molded. *(circa 1934)*







Polyvinyl chloride (PVC) is one of the most widely used thermoplastics in use today, particularly in the building and home construction industries where it is used for siding, window profiles & pipe.

The commercialization of PVC in 1927 is the direct result of research work that was conducted by Waldo Semon, a chemist working at the B.F. Goodrich Rubber Company. While PVC was already known at the time, it had no commercial value since it could not be processed without degrading. Semon discovered that PVC could be melt processed without degrading if a high boiling point liquid “plasticizer” was added to it. PVC formulations can be either rigid or flexible depending their plasticizer concentration. The very first applications for PVC included foul weather gear and electrical wire insulation.

1939: Wood TV Cabinet

Although polystyrene (PS) was unknowingly discovered by a German apothecary in 1839, it was not until 1930 that a scientist from the BASF Corporation developed a commercial process for the manufacture of PS. General purpose PS is a very transparent but fairly brittle thermoplastic. Shortly after its commercial introduction, other rubber modified or rubber toughened grades, known as high impact polystyrene (HIPS) were introduced.

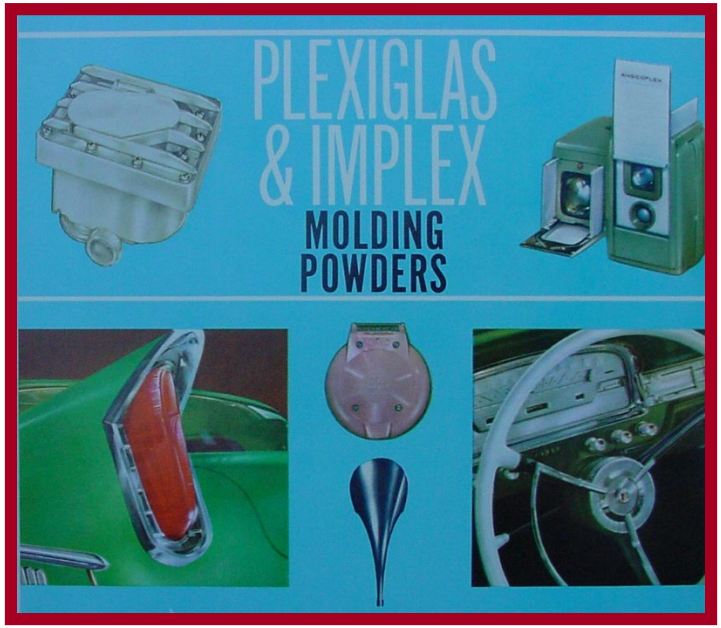
PS and HIPS are still widely today for items that range from razor cartridges to television cabinets. Television cabinets were initially wooden, then thermoset phenolic, followed by flame retardant HIPS that is still used today.

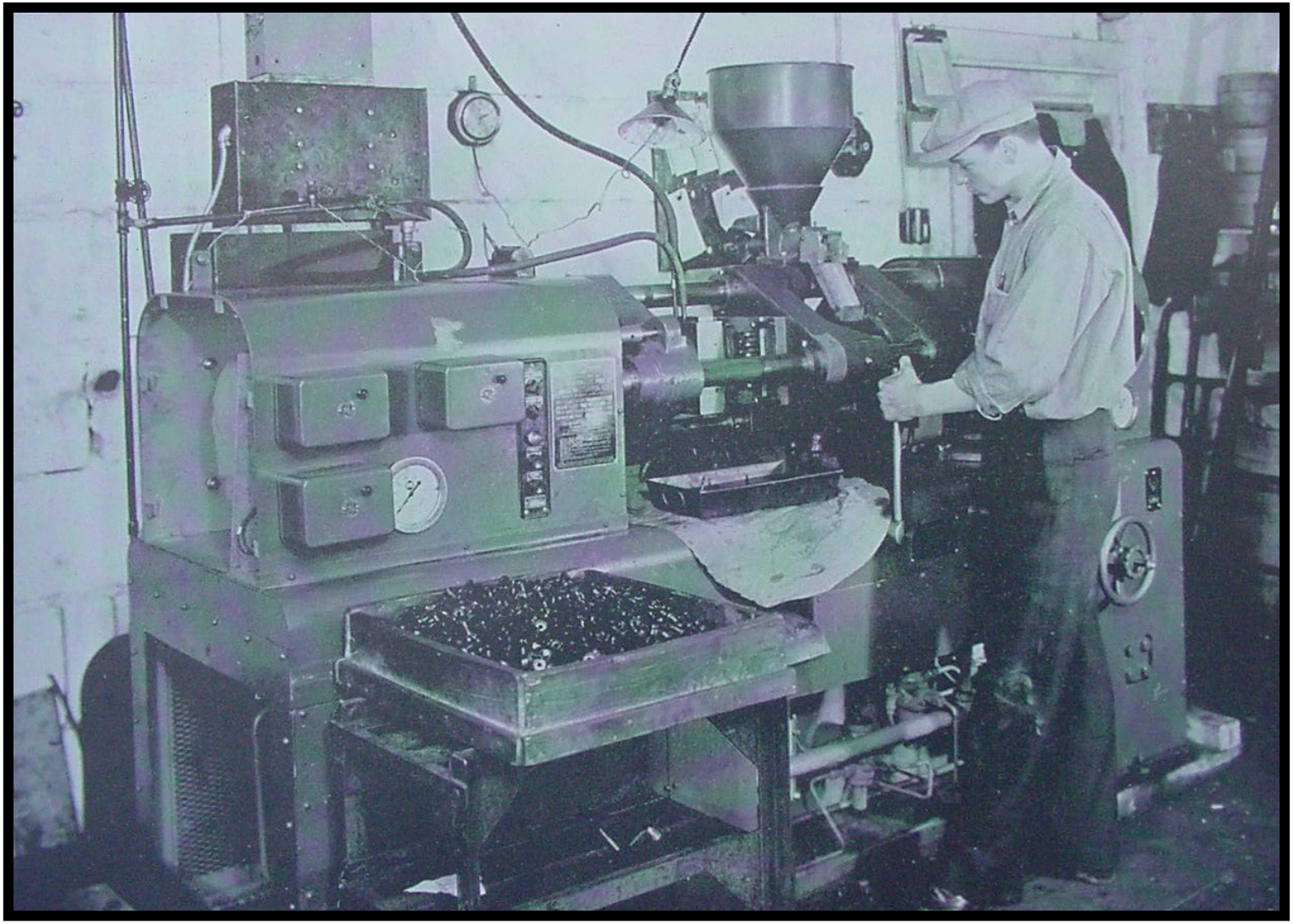
1948: Phenolic TV Cabinet

1970: HIPS TV Cabinet

2003: HIPS TV Cabinet

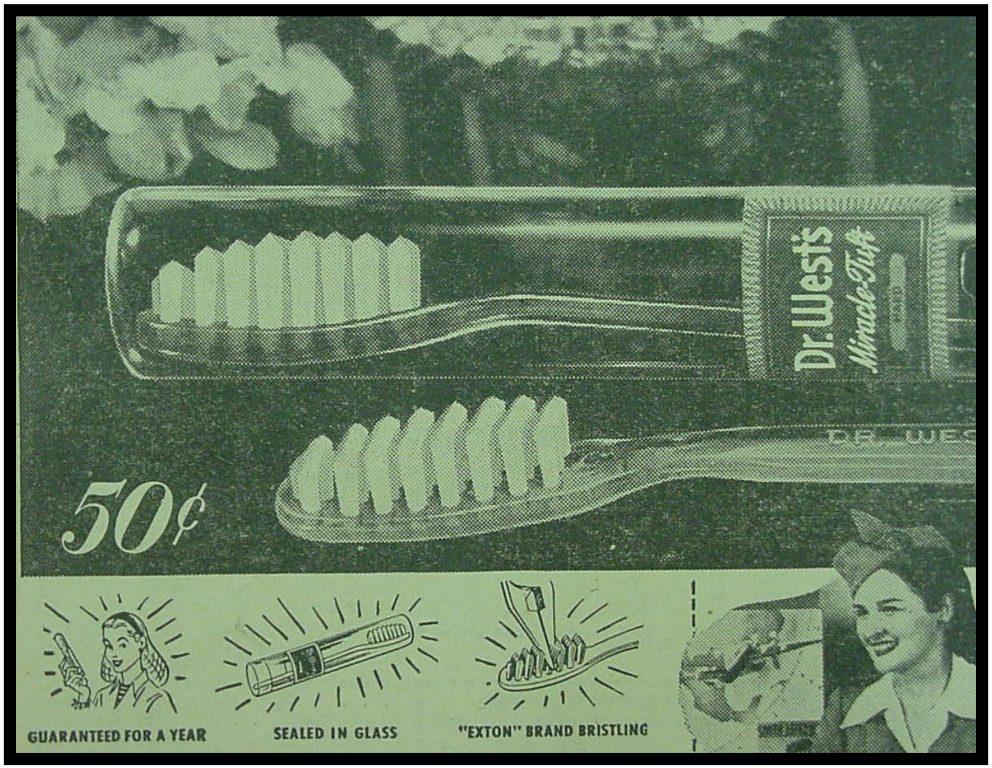
Rohm and Haas was the first company to market polymethyl methacrylate (PMMA), better known as "acrylic“. It was introduced commercially in 1937. Their tradename for this new thermoplastic was Plexiglas®. PMMA is a very hard material and is actually more transparent than glass. This transparent thermoplastic was first used for applications that ranged from contact lenses to thermoformed aircraft canopies. It then became the material of choice for automotive tail light lenses due to its superior optical properties, where it is still used today. PMMA is also used in a wide variety of other applications including acrylic fibers, paints and coatings, and as a marble replacement for kitchen countertops.





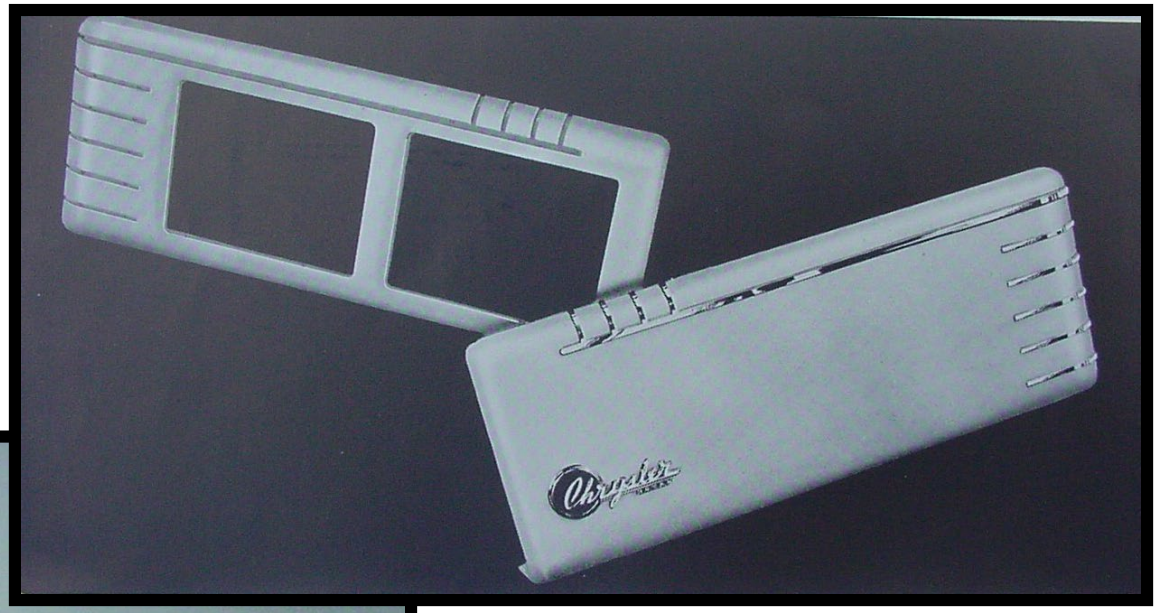
The process of *Injection Molding* involves injecting hot (melted) plastic into a closed mold cavity. Most early injection molding machines were imported from Europe. The IM machine shown below was one of the first US built machines and was manufactured by the HPM Corporation in Marion, OH. (*circa 1937*)

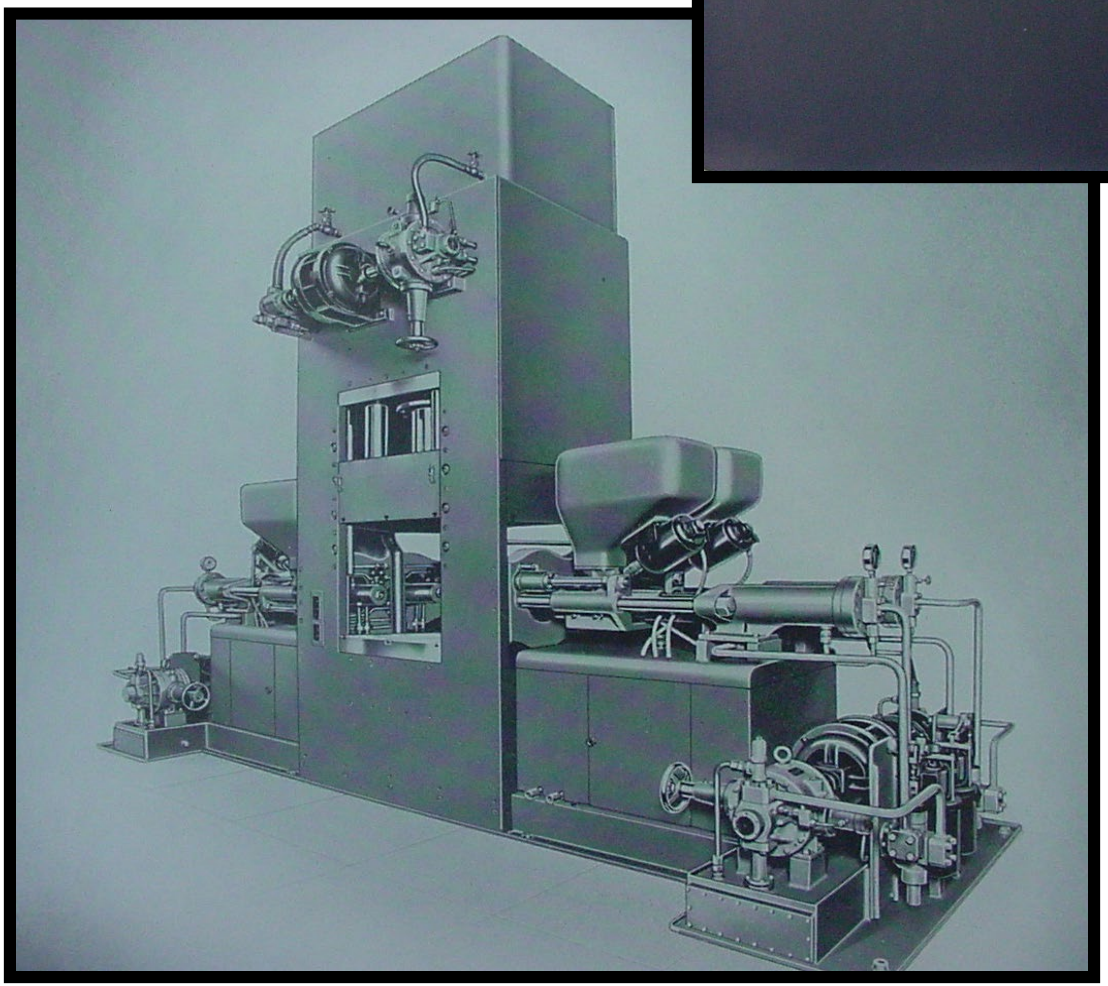
Dr. Wallace H. Carothers



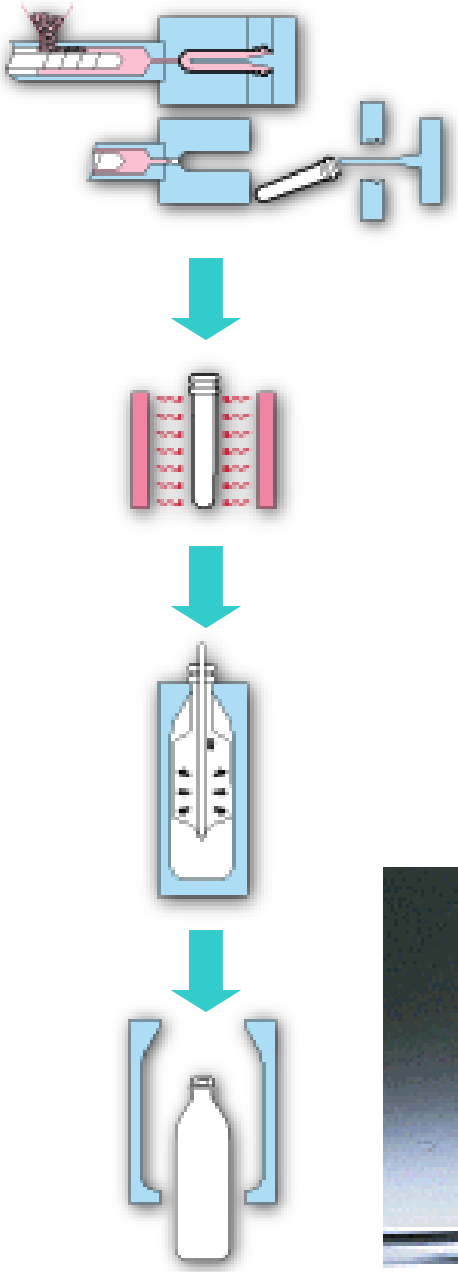
The E.I. duPont de Nemours Company wanted to develop a synthetic fiber that could replace silk. Shortly thereafter, duPont scientists, led by Dr. Wallace H. Carothers, pulled the first long, strong, flexible strands of a synthetic polymer fiber out of a test tube. They realized immediately that this artificial fiber had properties similar and in many ways superior to natural fibers. The material, *poly(hexamethylene adipamide)*, is more commonly known as “nylon 66”. It was intoduced commercially in 1938. One of the earliest uses of nylon 66 fiber was for tooth brush bristles, previously made from animal (Chinese boar) bristles. During World War II, nylon was used for many applications including cargo parachutes, tire cord for bombers, glider tow ropes, flak jackets, mosquito netting, and jungle clothing.

The first solution to molding “larger” plastic parts was a molding machine with *multiple injection units.*



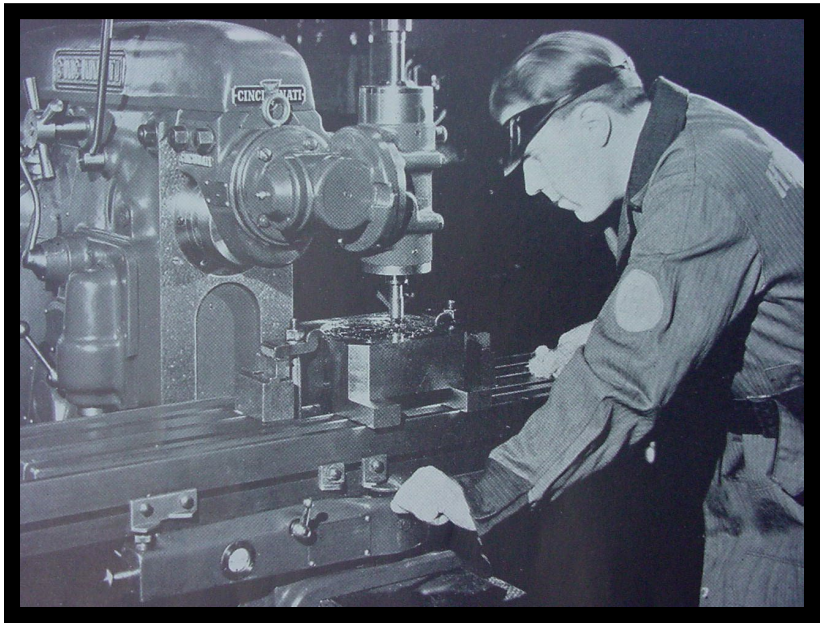


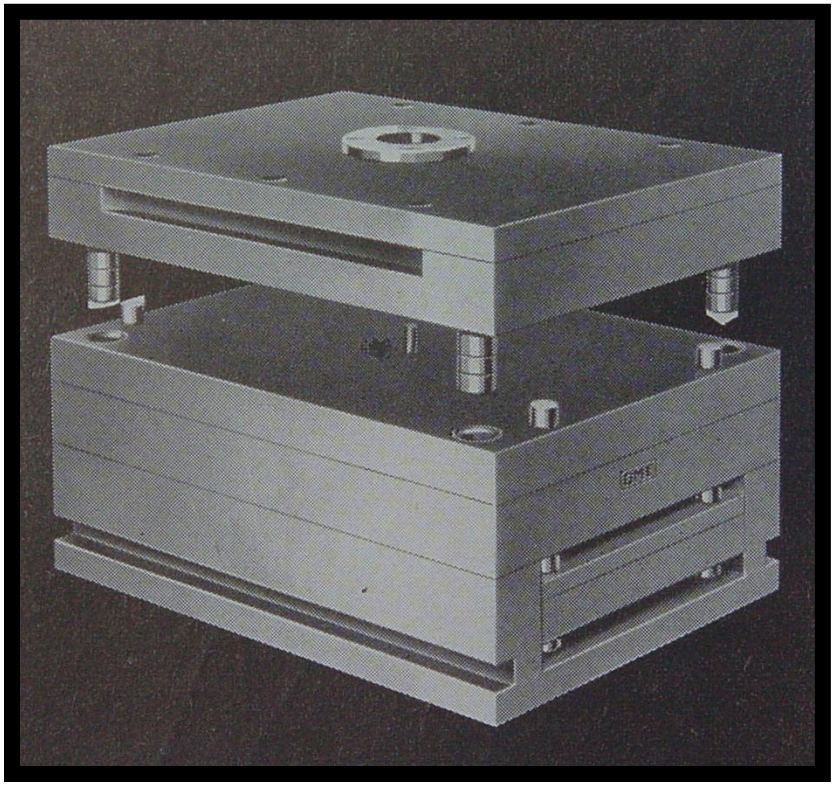
This 1939 HPM injection molding machine had four injection units giving it a total shot capacity of 32 ounces. It was used to mold the “very large” (for that time) automobile dash board parts shown above.



Polyethylene terephthalate (PET) is an extremely versatile thermoplastic made by the condensation reaction of ethylene glycol and terephthalic acid. Discovered in 1941, PET was initially used for the production of synthetic textile fiber, know today as *Dacron*®. Biaxially oriented PET film, known as *Mylar*®, is also widely used. However, the single largest use for PET is “stretch blow molded” beverage bottles. PET bottles are transparent, lightweight, have good barrier properties, and shatter resistant. Like most thermoplastics, PET is recyclable. In most cases, the recycled PET bottles are reprocessed to form PET textile fiber for clothing.

A major contribution to the mold making and molding industries was made by I.T. Quarnstrom, a toolmaker from Detroit, in 1943. He came up with the concept of producing “standard mold bases” having interchangeable components. The standard mold base would greatly simplify the machining process for plastic molds and reduce the time required to build injection and compression molds. The standard mold bases were produced by the DME Corporation that is still the leading supplier of mold bases today.



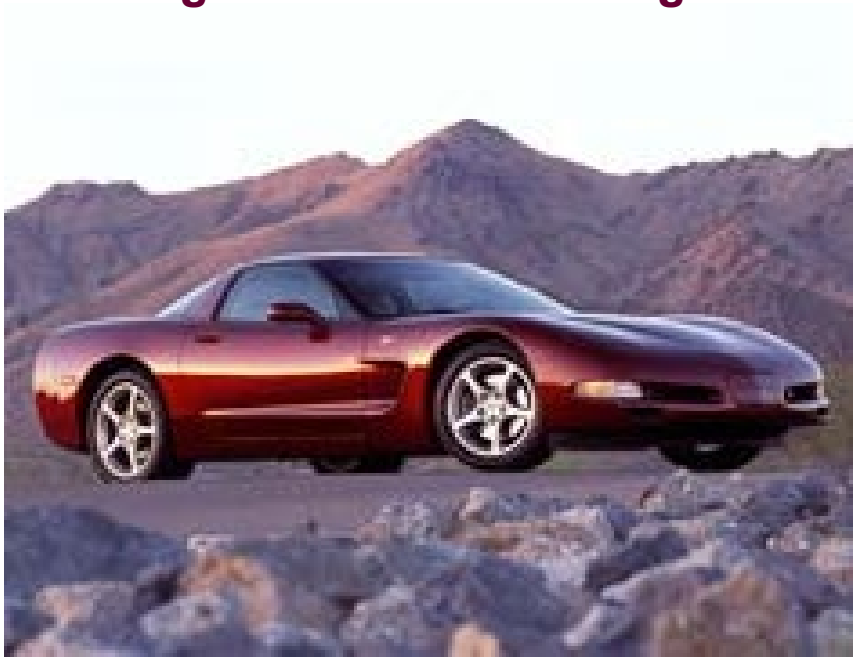


Dr. Roy Plunkett, a young scientist working at DuPont, accidentally discovers *polytetrafluoroethylene* (PTFE), an inherently slippery and remarkably chemically resistant plastic. It is said to be the most slippery substance on earth. The initial discovery occurred in 1938, but the commercial introduction of DuPont's *Teflon*® did not occur until 1946. *Teflon*® is most widely known for its widespread use in nonstick cookware and as cable insulation but it is used in a wide variety of other unique applications. *Teflon*® sheet is used as an insulator and lubricant between the copper skin and the stainless steel skeleton of the *Statue of Liberty*. It is also widely used for specialty textiles. The roof of the Pontac *Silverdome* is made of a *Teflon*® coated woven glass fiber fabric.

The tough thermoplastic known as ABS, short for polyacrylonitrile butadiene styrene, was first produced in 1951. At first, ABS was just a “blend” of polystyrene-acrylonitrile copolymer (SAN) and butadiene rubber as an impact modifier. However, the properties of the blend were not particularly good. It was then discovered that outstanding impact performance could be obtained if the SAN was chemically grafted onto the butadiene rubber. The grafted version is known as ABS “terpolymer”. The properties of ABS can be fine tuned by controlling the relative ratio of each monomer. ABS is widely used in applications where toughness is required. One of the earliest applications was for football helmets, which are now made from polycarbonate. Today, ABS is most widely used for consumer electronics and business machine housings.

General Motors introduced the Chevrolet *Corvette* in 1953. It was designed by GM's chief stylist Harley Earl, who was intrigued with the use of glass fiber reinforced plastic as a body material. A total of 300 *Corvettes* were produced in the first year of production, each containing forty one glass fiber reinforced unsaturated polyester body parts. The 1953 *Corvette* was available only with a white body and red interior, and sold for $3,498.00. While the Corvette has changed dramatically over its 50 year history, one thing that has not changed is the use of the glass fiber reinforced plastic body.

1953 Corvette



2003 50th Anniversary Corvette

Working independently, Hermann Schnell of Bayer A.G. in Germany and Daniel Fox of the General Electric Company in the US, both discovered *polycarbonate* in 1953. This optically transparent engineering thermoplastic offers a great balance of stiffness and toughness, heat resistance and electrical insulating properties. It is widely used for durable products such as automotive headlights, tool housings, helmets and computer enclosures. In more recent years, special grades of polycarbonate have been developed for optical recording media. Virtually all CD's, CD-ROM's and DVD's are manufactured using polycarbonate.

A number of scientists have been named Nobel Laureates for their pioneering work in the field of polymers or macromolecules. They include:

Hermann Staudinger for his many discoveries in the field of macromolecular chemistry. (1953)

Karl Ziegler and Giulio Natta for their discoveries related to polymer chemistry and new polymerization technologies. (1963)

Paul J. Flory for fundamental achievements, both theoretical and experimental, in the physical chemistry of macromolecules. (1974)

P.G. de Gennes for creating the reptation model of polymer dynamics used to predict polymer properties and viscosity. (1991)

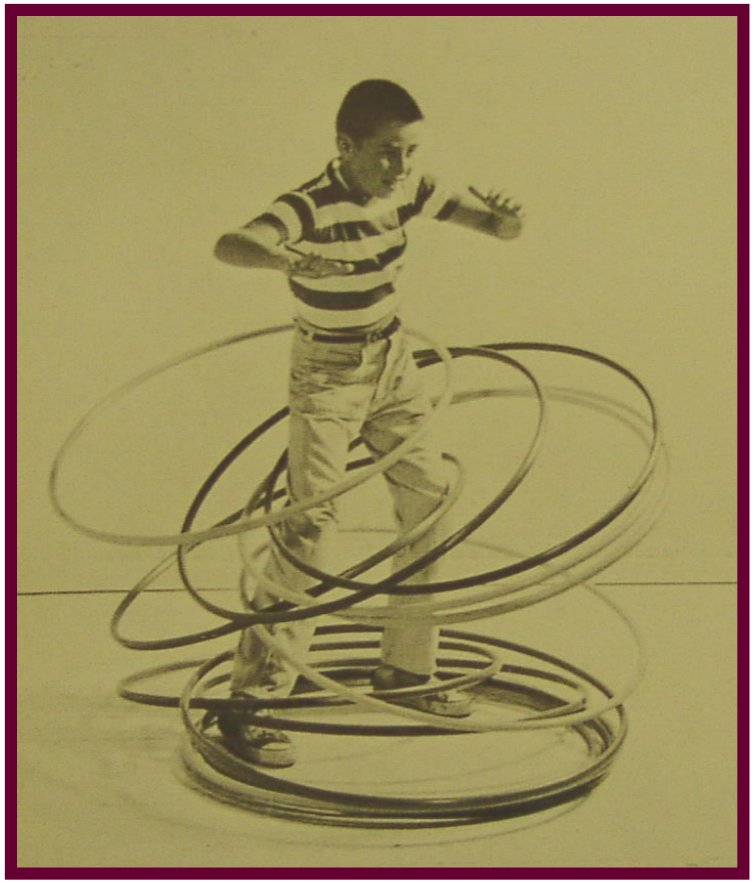
Alan J. Heeger, Alan G. MacDiarmid and H. Shirakawa for the discovery and development of inherently conductive polymers. (2000)

The Nobel Prize

The Plastics Engineering Program at UMass Lowell (then known as *Lowell Technological Institute*) was founded by the late Russell W. Ehlers in 1954.

High Density Polyethylene

The thermoplastic known as “high density polyethylene” (HDPE) was first produced commercially by Phillips Petroleum in 1955. It was given the tradename *Marlex* ®. This new thermoplastic offered a good balance of mechanical properties, low specific gravity, electrical insulation, and chemical resistance. However, the material had few markets in those early years. Then came the Hula Hoop !



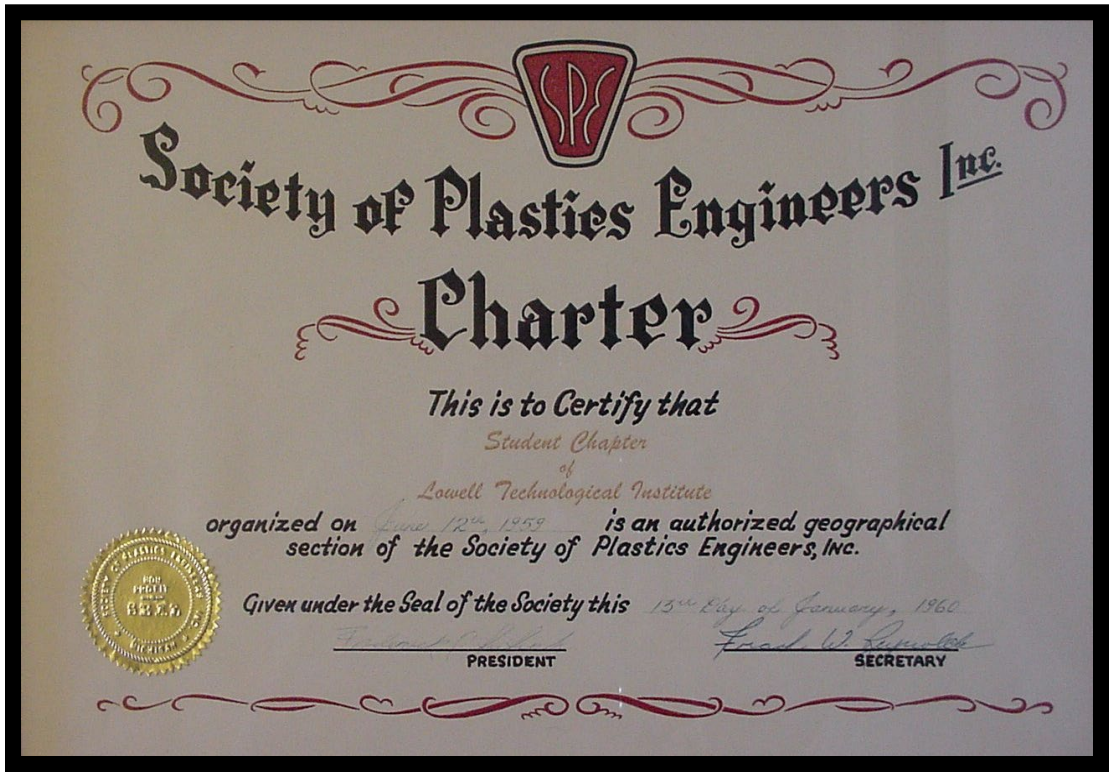
Richard Knerr and Artur Melin, founders of the Wham-O Company, were the architects of the biggest “fad” of all time – the “Hula Hoop”. The Hula Hoop evolved from bamboo hoops previously used in Australia. At the peak of this craze in 1958, Wham-O was using 1,000,000 pounds of HDPE each week for Hula Hoop production. They were the largest user of HDPE at the time.

The Monsanto *House of the Future* was constructed at Disneyland in 1957. The frame and structure of the house were 100% plastic. The house featured a number of innovations including a visual phone, an ultrasonic dishwasher, and a microwave oven. The house had four cantilevered wings floating above beautifully landscaped grounds and waterfalls. Like many concept designs, Monsanto's *House of the Future* was never mass produced. However, today the building and construction industry is one of the largest and fastest growing markets for plastics.

Working at the Milan Polytechnic Institute, Professor Guillo Natta had been examining propylene reactions attempting to find a new commercial polymer. The best efforts of other researchers had yielded only soft, gummy substances which showed no promise. His work was of great importance as it represented the first attempt to “engineer” a polymer molecule to a predetermined specification using a designed polymerization technology. The first "molecular mechanic" succeeded in 1954, building a long chain stereoregular polypropylene molecule. Polypropylene went into production in 1957 and is now a commodity plastic offering a very good balance of properties that include stiffness, toughness, chemical resistance, and translucent optics. One very unique characteristic of polypropylene is its ability function for thousands of cycles as an “integral hinge”. Polypropylene and its copolymers are among the most widely used thermoplastics. Professor Natta was awarded the *Nobel Prize* in chemistry for this work.

Plastics Engineering Education

The first student chapter of the *Society of Plastics Engineers* was established at the Lowell Technological Institute (now UMass Lowell) in 1959.


Society of Plastics Engineers Inc.

Charter

This is to Certify that

Student Chapter

of

Lowell Technological Institute

organized on June 12th, 1959 is an authorized geographical section of the Society of Plastics Engineers, Inc.

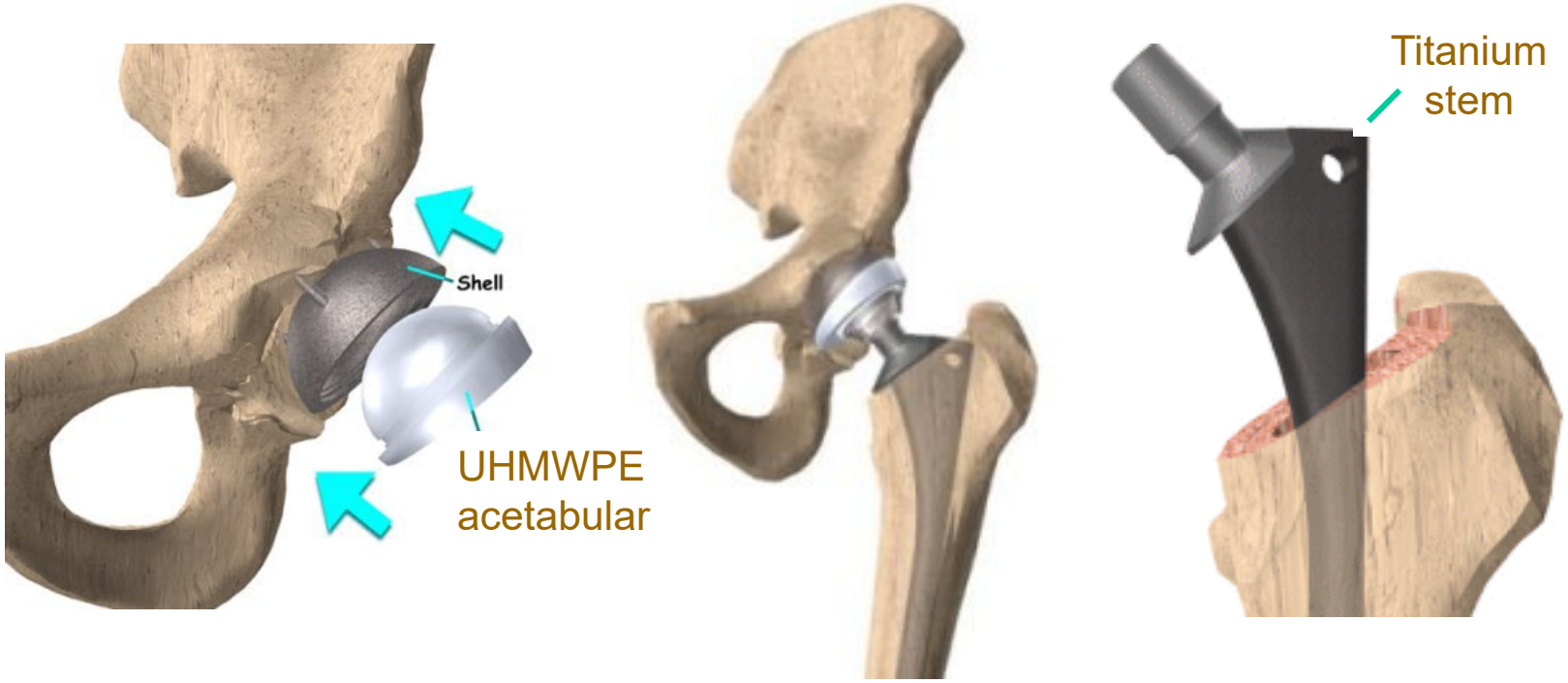
Given under the Seal of the Society this 13th Day of January, 1960

PRESIDENT

SECRETARY

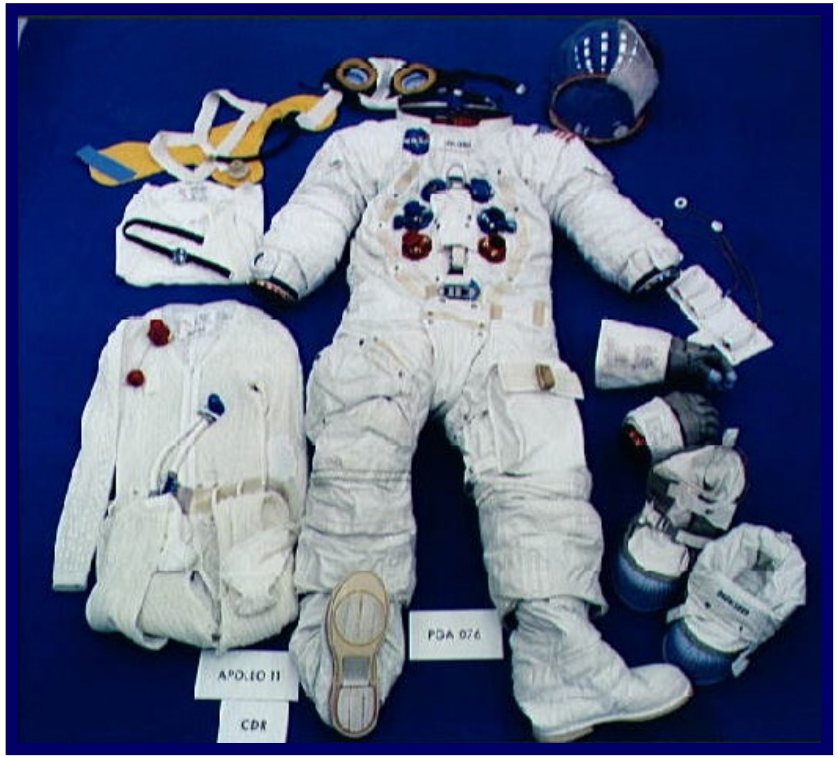
Today, there are 112 student chapters chartered by the *Society of Plastics Engineers* around the world.

Plastics are used extensively in the medical industry. One of the most interesting medical applications for plastics is the “artificial hip”. Each prosthesis is made up of two parts: the acetabular component (socket portion) that replaces the acetabulum, and the femoral component (stem portion) that replaces the femoral head. The femoral component is made of titanium, while the acetabular component is made of a metal shell with a plastic inner socket liner. The plastic liner is molded from *Ultra High Molecular Weight Polyethylene* and acts like a bearing. The UHMWPE is extremely tough, abrasion resistant and has a very low coefficient of friction. This is a very good example of how plastics and metals work together to enhance our quality of life.



The Graduate, starring Dustin Hoffman, is released by Embassy Pictures in 1967. A memorable poolside scene from the movie:

Mr. McGuire:	***Come with me for a minute. I want to talk to you. I just want to say one word to you. Just one word.***
Ben:	***Yes, sir.***
Mr. McGuire:	***Are you listening ?***
Ben:	***Yes sir, I am.***
Mr. McGuire:	**PLASTICS.**
Ben:	***Exactly how do you mean ?***
Mr. McGuire:	***There is a great future in plastics. Think about it. Will you think about it ?***
Ben:	***Yes I will.***



On July 20, 1969 – the human race accomplished its greatest technological achievement of all time when Neil Armstrong set foot on the moon. This feat would not have been possible without many materials science developments. Plastics played an important roll. For example, the *Apollo* A7L space suits were a multi-layer plastic structure comprised of nylon fabric, neoprene coated nylon fabric, *Dacron*® (PET) fabric, aluminized *Mylar*® (PET) film, *Kapton*® (PI) film, and *Teflon*® (PTFE) coated fabric. The "fish bowl" helmet was produced from transparent polycarbonate. The space suits of today make even more extensive use of plastics.

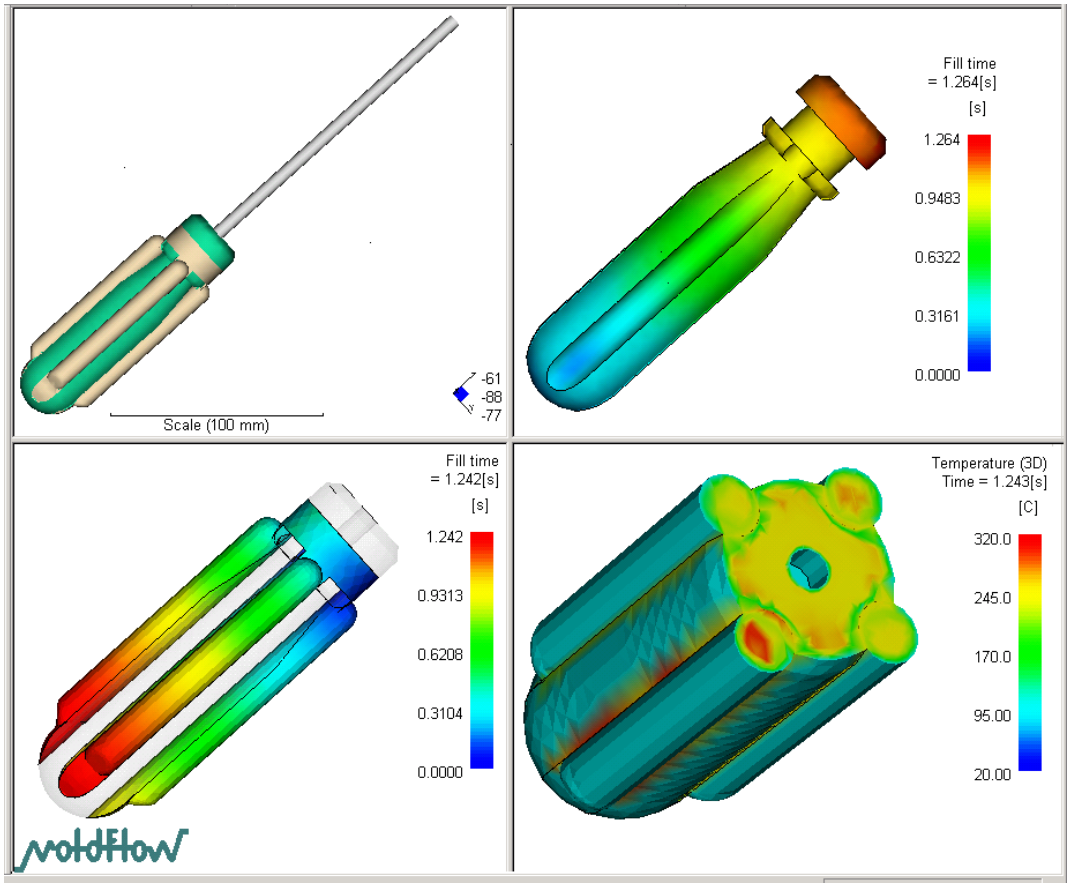
Stephanie Kwolek

Relying on experience and instinct, Stephanie Kwolek invented one of the modern world's most readily recognized and widely used materials: *Kevlar*®. Kwolek, a DuPont chemist, specialized in low-temperature processes for the preparation of condensation polymers. In the 1960's, she discovered an entirely new branch of synthetics known as liquid crystalline polymers. She discovered an aramid polymer that most researchers would have rejected, since it was fluid and cloudy, rather than viscous and clear. Kwolek, acting on instinct, insisted on spinning out the solution, and the result was astonishing: synthetic fibers much stiffer and stronger than any created before. The polymer fiber, named *Kevlar*®, was first marketed in 1971. The fiber was five times stronger than steel (on a strength per weight basis) but about half the density of glass fiber. *Kevlar*® is best known to the public as the material from which bulletproof vests are made; and in this use alone has saved thousands of lives. In fact, *Kevlar*® has dozens of important applications, including radial tire cord, brake pads, racing boat sails, aircraft components, and suspension bridge cables.

Battenfeld Gloucester

Over the years, Battenfeld Gloucester, formerly Gloucester Engineering, has been responsible for a number of innovations related to film extrusion, especially in the area of multi-layer film extrusion. The blown film extrusion process, such as that shown above, is used to produce everything from food packaging to agricultural film. The company is also the sponsor of the *Battenfeld Gloucester Film Extrusion Laboratory* here at UMass Lowell.

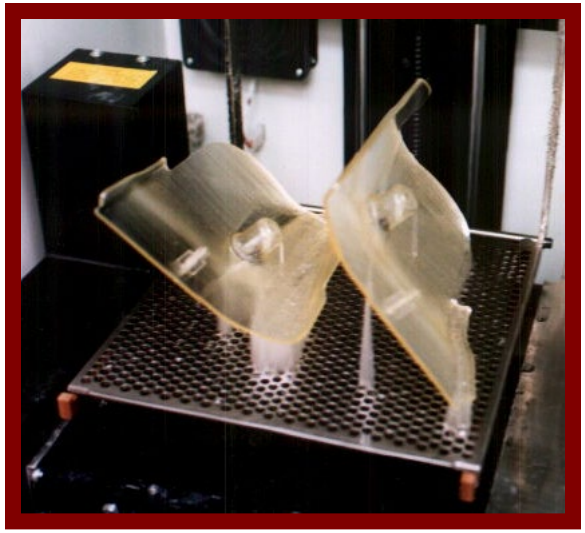
In the 1974, Edward Klobbie, a plastics process engineer from the Netherlands, developed a process that could be used to manufacture **"plastic lumber"** from waste post consumer plastic packaging. Plastic lumber can be manufactured from a variety of waste streams, however, it is most commonly produced using post consumer HDPE milk or detergent bottles. Wood fiber or saw dust is often added to the plastic lumber as a reinforcing filler. Plastic lumber offers a number of advantages for outdoor applications where it competes with pressure treated wood lumber. Plastics lumber is used for applications such as porches or decks, park benches, landscape timbers, and even railroad ties. It is rot proof, durable, and virtually maintenance free.



The *Moldflow* Corporation revolutionized the plastic part and mold design fields when it introduced "Injection Molding Simulation" software in 1978. Founded in Australia by Colin Austin, *Moldflow* was the first company to produce software that allowed plastics engineers to optimize the design of their parts and molds before "cutting steel". *Moldflow*, now headquartered in Wayland, MA is dedicated to improving the *Design to Manufacture Process* for injection molded plastic parts.

Polyurethane could be the most versatile plastics available today. A polyurethane is formed by reacting a polyol (an alcohol with more than two reactive hydroxyl groups per molecule) with a diisocyanate or a polymeric isocyanate in the presence of suitable catalysts and additives. Polyurethanes can be molded, extruded, or cast, and are available as foams, coatings, specialty adhesives and sealants. The flexible and durable vertical body panels of the Pontiac *Fierro* were reaction injection molded polyurethane. The first artificial replacement heart, the *Jarvic-7*, was produced from a flexible and fatigue resistant polyurethane. The toughness and abrasion resistance of polyurethane make it an ideal material for applications such as in-line skate wheels.

Prototyping is a very important step in the new product development process. In 1982, Charles Hull first conceived the idea of the “Rapid Prototyping” process known as *StereoLithography*®. This rapid prototyping equipment, produced by 3D Systems in Valencia, CA, is a fully automated system for the production of prototype plastic parts. The process begins by slicing a “solid computer model” of the proposed part in thin (virtual) layers. A focused ultraviolet laser beam then shines onto a photosensitive liquid epoxy plastic resin bath at selected locations causing the epoxy to polymerize and solidify. The part is built or “grown” one layer at a time. Using this process, prototype parts can be built in a matter of hours, rather than days or weeks as with traditional machining. This has revolutionized the product development process and reduced time to market for new products.



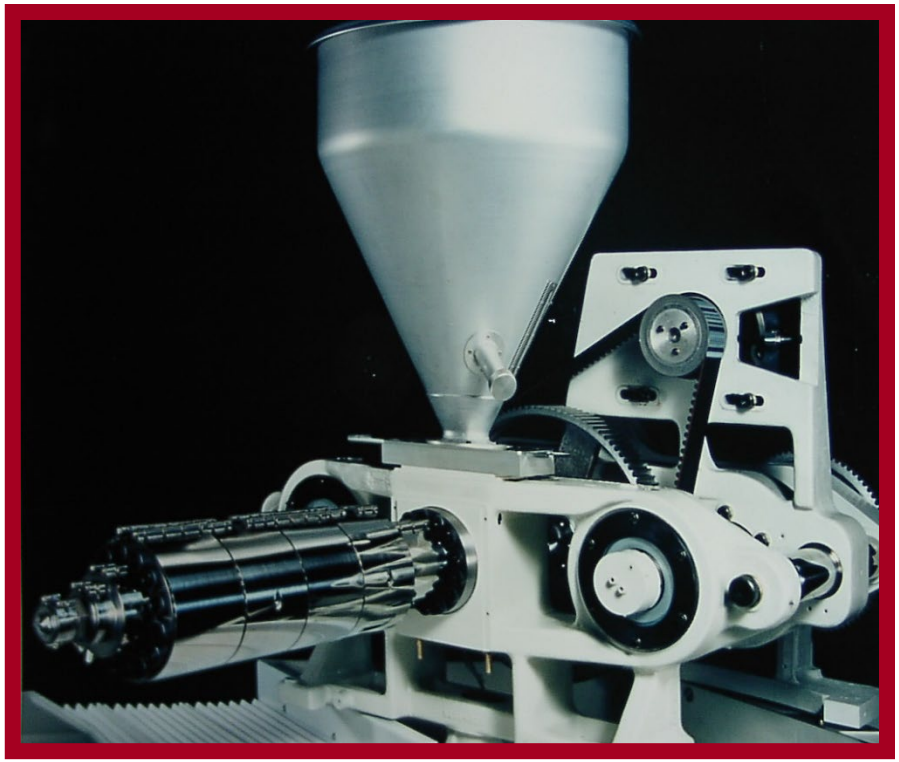
In search of a high temperature thermoplastic, scientists at the General Electric Company discovered polyetherimide (PEI) in the early 1980's. The material was introduced commercially in 1982 with the tradename *Ultem*®. The transparent amorphous thermoplastic has mechanical properties very similar to polycarbonate, but has much better heat resistance. It can be used at temperatures up to 365ºF for an extended period of time. It is also inherently flame retardant and very lightweight. The combination of these properties make *Ultem*® the ideal material for applications such as the thermal imaging camera case and firefighter helmets shown below.

NATIONAL PLASTICS CENTER & MUSEUM

1982 to 2002

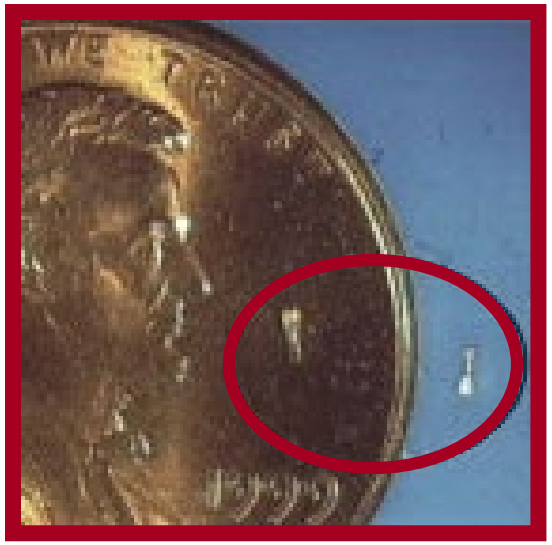
The *National Plastics Center and Museum* is a non-profit institution dedicated to preserving the past, addressing the present, and promoting the future of plastics. Incorporated in 1982, the NPCM offers a rich and diverse experience for visitors of all ages. The center and museum is located off route 117 in Leominster, Massachusetts, a town rich in plastics history. In fact, Leominster is said to be the "birthplace" of the plastics industry.

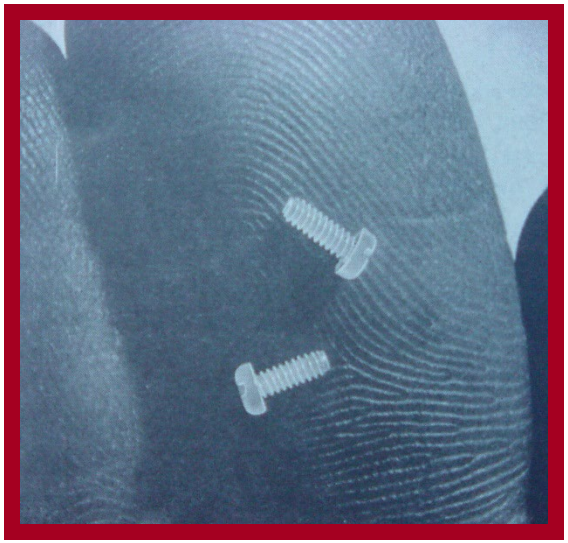
MILACRON
Manufacturing Technologies



The Milacron Corporation was the first injection molding machinery manufacturer to offer an “ALL ELECTRIC” injection molding machine. The unique *ACT* machine series was developed jointly with the Fanuc Corporation and was introduced in 1985. Every machine function was controlled by a separate electric servo-motor (rather than hydraulics). These revolutionary molding machines offered unprecedented precision and energy efficiency compared to their conventional hydraulic counterparts. Today, more than 35% of the molding machines Milacron Ferromatic sells are “ALL ELECTRIC”.

The emerging field of “Micro Injection Molding” is in its infancy today. In recent years, injection molding machinery suppliers have started to manufacture very small scale molding machines, having clamp tonnages as low as three tons and shot capacities less than a gram. Now that this equipment is available, microscopic plastic parts can be manufactured with unprecedented precision. The micro molded plastic medical parts shown on the left below are molded by *Miniature Tool and Die* in Charlton, MA and weigh just 0.00012 grams each. The Micro Injection Molding Lab at UMass Lowell’s Plastics Engineering Department is sponsored by *Sumitomo Plastics Machinery*.



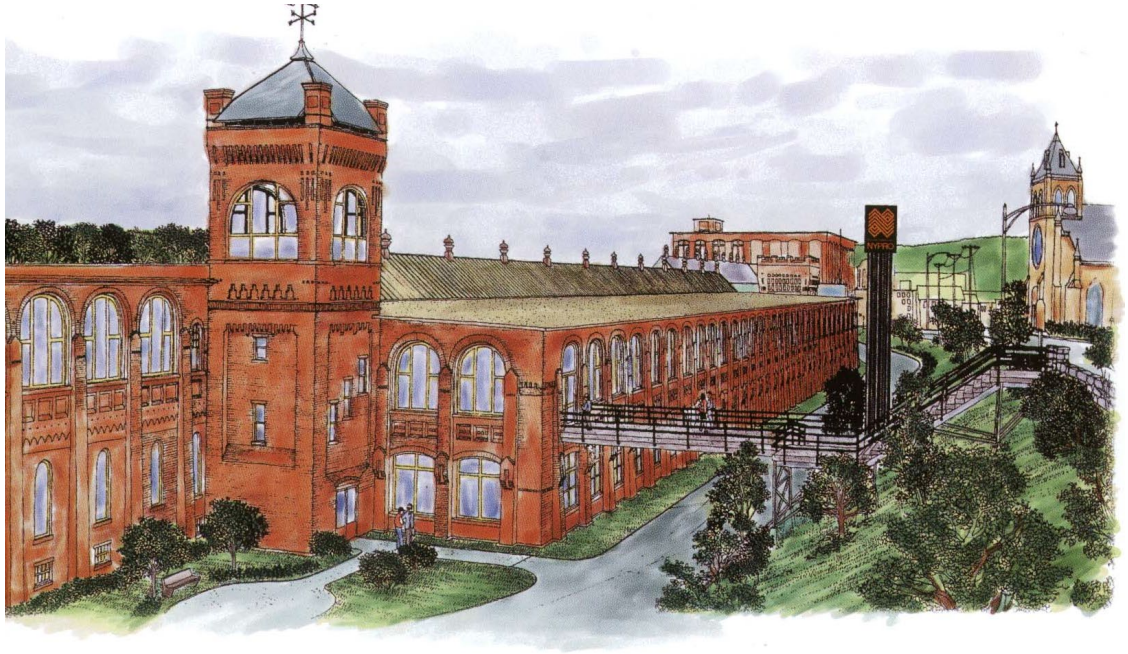


In the mid 1980's, General Motors Chairman Roger Smith set out to "rethink" the way automobiles were designed and manufactured. Working with a clean slate, GM rethought everything from marketing to materials of construction to manufacturing. Plastics played a large roll in this effort. The new automobile, the *Saturn*, was the very first passenger vehicle to make extensive use of injection molded "thermoplastics" for exterior body panels. Most of the *Saturn's* body panels are molded from a blend of polycarbonate and acrylonitrile butadiene styrene (PC/ABS). The use of the PC/ABS gave designers much greater design freedom when compared to traditional sheet metal body panels. The PC/ABS body is also, lightweight, corrosion resistant and durable.

The very first *Saturn* was driven out of the Spring Hill Tennessee assembly plant by Roger Smith himself on July 30, 1990. More than 2.5 million *Saturns* have been produced since that time.

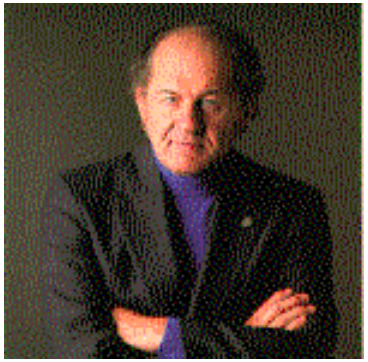
Plastics have been used for telephone housings since the turn of the last century. The early black plastic phones were compression molded from thermosetting phenolic and had wall thicknesses up to 13 mm. Injection molded ABS phones were introduced in the 1950's. ABS has a very high gloss, good impact resistance, and unlike phenolic, could be molded in a variety of different colors. The ABS phones had wall thicknesses of about 3 mm. Today's cell phones are injection molded using a polycarbonate & ABS blend (PC/ABS). The compact and lightweight phones of today have wall thicknesses in the range of 1 mm. Telephones are a good example of how plastic products evolve over time. Creative product designers make use of new plastic materials and new plastic processing technologies as they become available in order to improve product performance.

The NYPRO Corporation, with headquarters in Clinton, MA, is a leading global supplier of precision injection molded assemblies and tools. The company was founded in 1955 as the *Nylon Products Corporation* with annual sales of less than $1 million. Using borrowed funds, the company was purchased by Gordon Lankton in the 1960's. Today, the company has more than 30 manufacturing facilities around the world, including facilities in the UK, Germany, Russia, India, Mexico, Hungary, and China. NYPRO, sponsor of UML's "Precision Injection Molding Laboratory", has annual sales that now top $800 million. This year, NYPRO will mold and assemble more than 6 billion plastic parts. That is one part for every man, woman, and child in the world.



Nypro

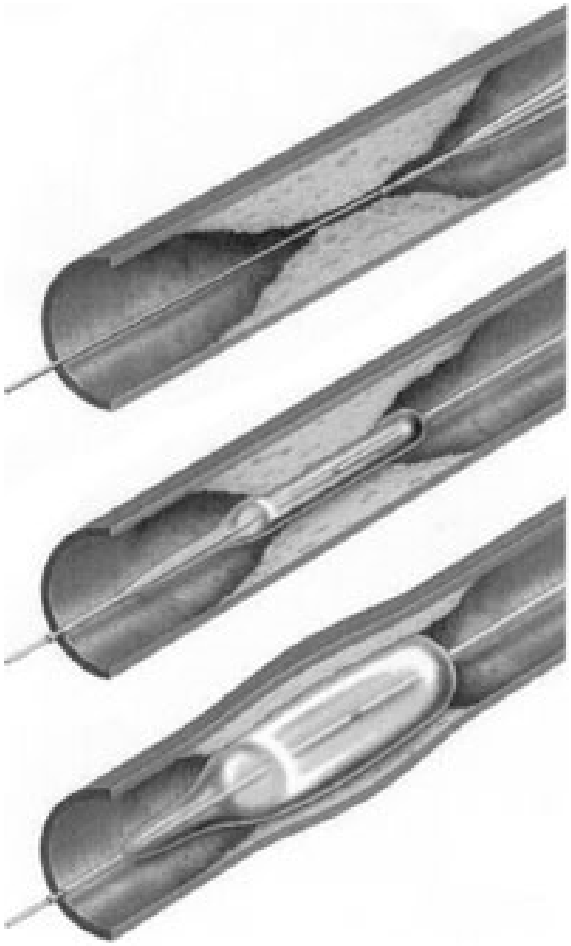
Mico Kaufman, a Tewksbury sculptor, is most famous for his traditional metal artwork. As a sculptor, his bronze artworks include the “Homage to Women” and “Indian Maiden” which are both located in Lowell. He is also well known for his *Presidential Inaugural Metals*, including those of Presidents Ford, Regan and Bush. Always on the lookout for new ideas, Mico found his next artistic medium — molten plastic. "I finally felt that I had a medium, had the material, where only the imagination was the limit," he says. "I was letting my hair down and doing something that I always wanted. Each type of plastic has a temper and personality of its own, so everything you do inspires you to do something more.“ Over the past ten years, Mico has been creating plastic artwork in the laboratories of the Plastics Engineering Department at UML. The artwork is created by forming strips of molten plastic as it exits an “extruder”. Mico has produced more than 30 plastic sculptures including the one to the right.



Mico Kaufman

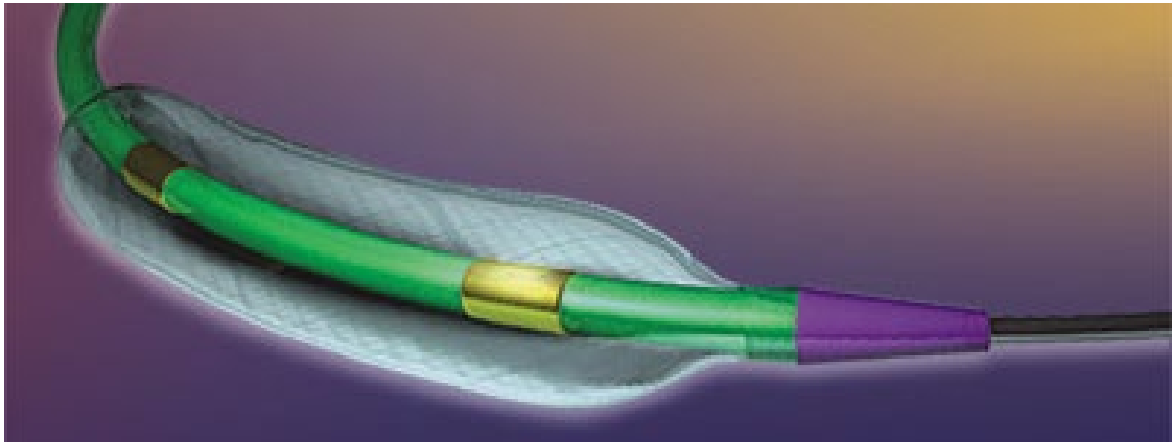
“Very Large” Part Injection Molding

This HUSKY 8800 ton clamp injection molding machine is being used to mold “thermoplastic” Jeep Wrangler® hardtops. This is one of the largest injection molded parts ever made.

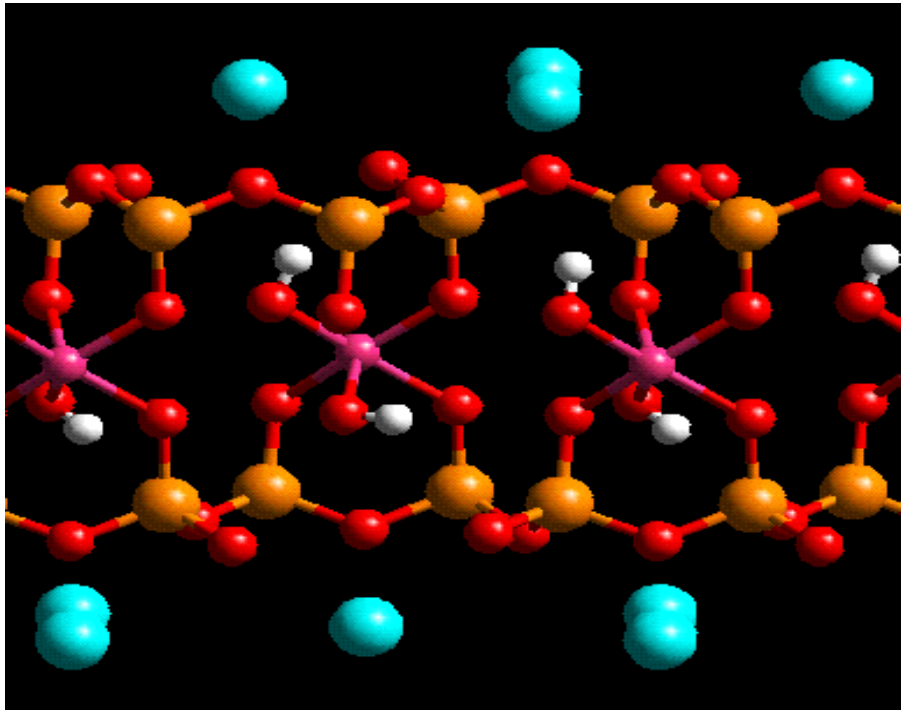


Some of the most advanced plastic products being manufactured today are used in the medical industry. The angioplasty catheter is a good example of a life saving medical device that would not be possible without plastics. Balloon angioplasty is a minimally invasive non-surgical alternative to coronary artery bypass grafting surgery. The angioplasty balloon is used to compress obstructing plaque in a clogged artery against the arterial wall so that blood can flow freely again. The doctor positions the balloon of the angioplasty catheter at the site of the blockage and gently expands it to compress the plaque and create a wider opening in the artery. This procedure has a very high success rate and greatly reduces the chances of surgical complications.

Angioplasty balloons are made from a variety of plastics including PET, nylon 11 or nylon 12.



The exciting new materials science field known as “nanoscience” has a number connections with plastics. For example, nanocomposites are plastics that are reinforced with very finely divided and dispersed nanoclays or nanofibers. These nanocomposites can offer unprecedented mechanical performance and barrier properties.



The minivan step shown above is produced using a nanoclay reinforced thermoplastic.

The plastics industry started in the late 1800's with plastics produced from natural resources. These included plastics based on shellac, cellulose and natural rubber. As the petrochemical industry developed in the 1900's, a wider variety of synthetic plastics were introduced and production of plastics based on natural resources declined even as the overall consumption of plastics rose. These synthetic plastics had more consistent quality and properties, and could be produced at a lower cost.

As the world develops, the demand for our non-renewable and limited resources has grown rapidly. This has led to feedstock shortages and petrochemical price increases. Ironically, manufactures of plastics are now turning back to natural and renewable resources for manufacturing plastics, as they did in the 1800's. This plastic coffee mug shown above is produced from poly(lactic acid), a thermoplastic that is derived from corn. Many of these agricultural based plastics are also biodegradable.