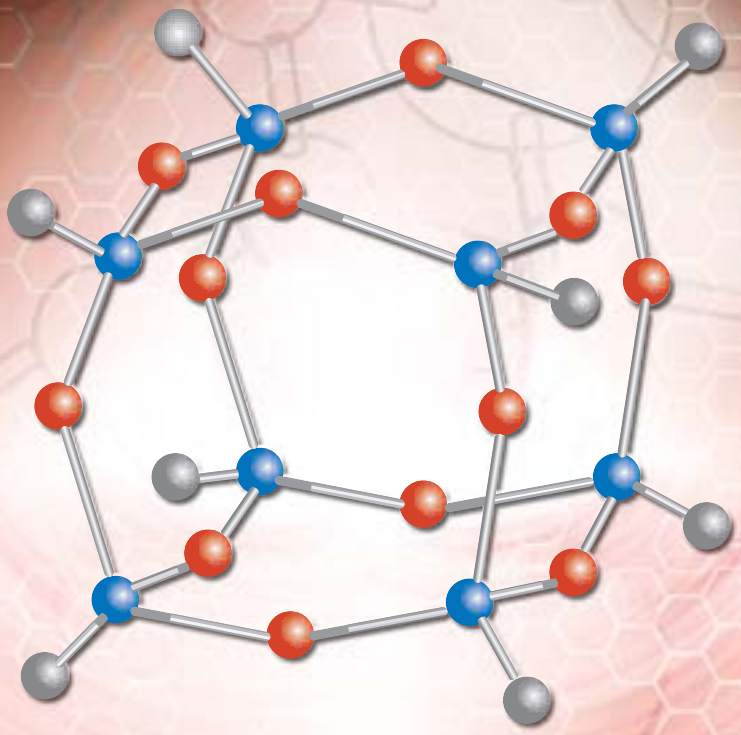
NANOTECHNOLOGY

For Ohio's Plastics Industry



WTN
Wright Technology Network
Transferring Technology that Transforms Business

The Ohio Nanotechnology Commercialization Initiative

The Ohio Nanotechnology Commercialization Initiative

The goal of this initiative is to expand the awareness and understanding of nanotechnology by Ohio's plastics industry. The initiative is specifically focused on nanotechnologies developed by Air Force Research Laboratory (AFRL) and Ohio-based companies. This brochure describes nanotechnology, it's importance and use, and nanotechnology examples.

There are many nanomaterials available, some of which are applicable to the plastics industry. This brochure discusses two families of nanomaterials that would significantly benefit the plastics industry - POSS ™ and Pyrograf ® III.

Nanotechnology is one of the most important emerging technologies for the next thirty years. It will change information technology, biotechnology, materials and manufacturing - just about everything - including our personal and social health. According to Mihail C. Roco (National Science Foundation), "Nanoscale science, engineering, and technology are seen as emerging, strategic areas for the next decades that will be the backbone of the next industrial revolution."

The goal of this initiative is to introduce nanotechnology to Ohio's plastics industry. Six of the top 20 compounding companies are headquartered in Ohio, and they can benefit greatly from nanotechnology.

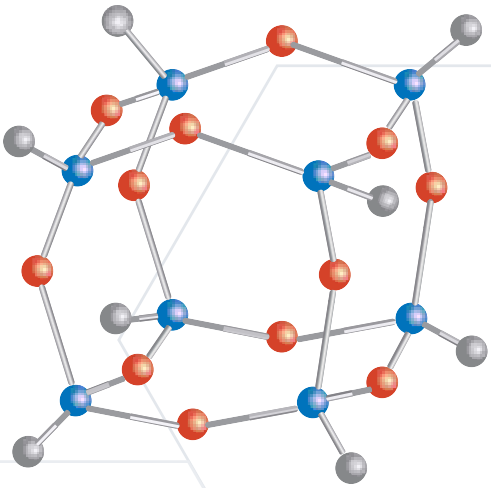
The Wright Technology Network has a special technology transfer role with the Air Force as the Partnership Intermediary for Air Force Research Laboratory at Wright-Patterson Air Force Base. The state of Ohio supports the AFRL-WTN partnership and, through technology commercialization initiatives like this one, has asked WTN to help ensure the global competitiveness of Ohio industries.

Description of Nanotechnology

And It's Importance To Materials Science

What is Nanotechnology?

Nanotechnology is the science of small. The term "nanotechnology" comes from nanometer, which is one-billionth of a meter long. This unit of length is roughly the width of five atoms across and is 10,000 times smaller than the diameter of a human hair. Materials with dimensions in the nanometer range have the ability to intimately interact on the molecular level with other molecules such as macromolecules (polymers), resulting in unique physical, chemical, and electrical properties.



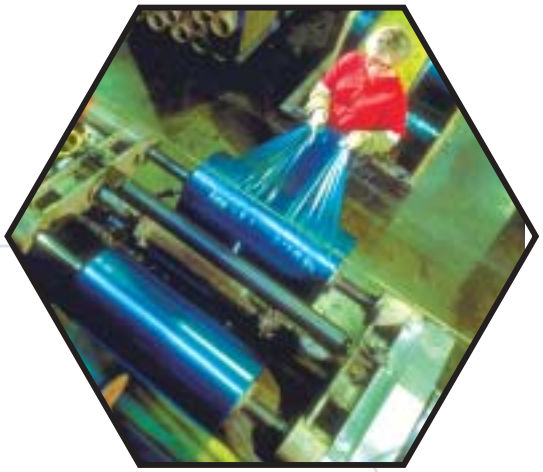
The materials scientist has continuously sought to improve the properties of existing polymers by blending with fillers or alloying with other polymers. This technique has produced many commercially useful products. The addition of nano-sized fillers is not new. For over 100 years nano-sized carbon black has been added to polymeric materials. The emerging field of nanotechnology has now given the materials scientist new tools to greatly improve the properties of existing plastics. The Nanostructured ™ Chemicals, Polyhedral Oligomeric Silsesquioxanes - POSS ™ for short - (developed by The Air Force Research Laboratory and now supplied by Hybrid Plastics ™, Inc., Fountain Valley, California) and Pyrograf ® III multi-walled carbon nanofibers (supplied by Pyrograf ® Products, Inc., an affiliate of Applied Sciences, Inc., Cedarville, Ohio) are two families of revolutionary nano-sized materials which can dramatically change the properties of existing plastics or result in polymers with enhanced properties.

The Importance of Nanotechnology

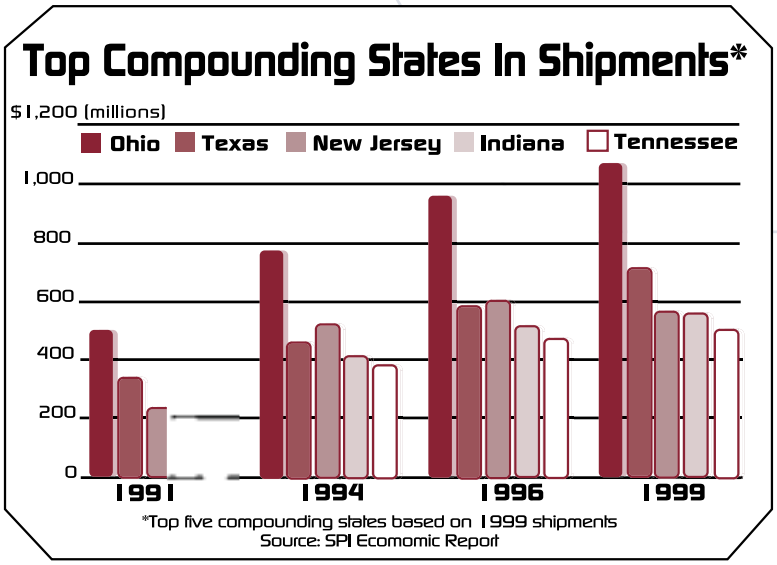
To Ohio's Plastics Industry

Why is Nanotechnology Important to Ohio's Plastics Industry?

The plastics industry represents a dynamic economic force in the United States. In 2000, over 100 billion pounds of polymers and elastomers were produced. Sales of compounded plastic materials reached $5.5 billion. Ohio is home to 6 of the top 20 compounding companies. These six companies command over 20 percent of the total U.S. market for compounded plastics. Ohio leads the nation in the sale of compounded plastics. Nano-sized additives such as POSS ™ or Pyrograf ® carbon nanofibers can be used by compounders to produce plastic materials with significantly enhanced properties.



The plastics industry is a major component of Ohio's economy. More than 2,500 Ohio companies are involved in the plastics industry and they account for over 120,000 jobs with $3.7 billion in annual wages. And they have $980 billion in capital investment. Making companies aware of emerging technology is a prime method of keeping Ohio's plastics industry strong and competitive. POSS ™ materials and Pyrograf ® carbon nanofibers are two important emerging technologies that can help ensure the competitiveness of Ohio's plastics industry.



Use of Nanomaterials

In Plastics

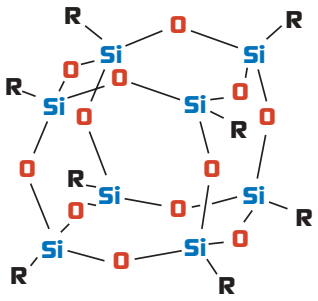
How are nanomaterials used?

Due to their unique size, nanomaterials can greatly enhance the performance of plastic materials. Nanosized particles for the most part are smaller than macromolecules (molecules that make up plastic materials), and, due to their very large surface area relative to their volumes, have strong interactions with macromolecules. In addition, the elemental composition of some nanomaterials will lend unique properties to plastic materials.

The POSS ™ molecular silicas can be blended into existing plastics by well-established methods such as a twin screw extruder, high intensity mixer, or two-roll mill. Once blended into an existing plastic, the nanosized silicon-oxygen cage structure will reinforce the amorphous portion of the macromolecule. The result is a substantial increase in properties such as tensile strength, modulus, and more importantly, the heat distortion temperature. Addition of POSS ™ compounds to existing plastics will also improve flame retardency in that a silica layer, which prevents oxidation, is formed at the onset of burning. POSS ™ materials can also be used as surface modifiers to dramatically improve the dispersion of commonly used fillers in existing plastic materials. Hundreds of uses of POSS ™ in conjunction with plastics have been identified, such as the preparation of selective pore sized membranes and flame retardant fibers. Dental restoratives with greatly reduced crack propagation have been formulated using the POSS ™ materials.

Pyrograf ® III carbon nanofibers can also be blended into existing thermoplastics, thermoset plastics, and elastomers by known mixing techniques. Pyrograf ® composite formulations can be prepared from polyolefins such as polypropylene, from engineering thermoplastics such as polyamide (nylon), from thermosets such as polyesters, and from various elastomeric materials such as rubber compounds. Pyrograf ® nanofibers can be used as a conductive filler at very low loadings in plastics for antistatic plastics and EMI applications. Thermoplastic and thermoset materials can be made very conductive to the point that these plastics can be used as pliant electrical contacts. Other uses include the manufacture of structural components from available thermoset resins with improved tensile strength and modulus properties. The heat distortion temperature of commodity plastics can be increased to that of engineering thermoplastics with the addition of moderate amounts of Pyrograf ® carbon nanofibers. The utility of these unique carbon nanofibers is as diverse as one's imagination.

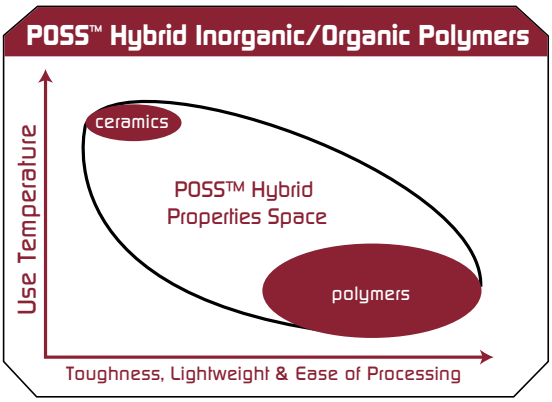
Polyhedral Oligomeric Silsequioxanes (POSS™)



An example of a family of Nanomaterials.

The POSS ™ Nanostructured ™ Chemicals, which are available from Hybrid Plastics ™ Incorporated, are the first entirely new chemical feedstock advancement within the past 50 years. The POSS ™ chemicals are a family of materials with over 120 different materials commercially available. The silicon-oxygen framework provides the inorganic core of the POSS ™ cage.

The carbon "R" groups (organic) located on the silicon atoms aid in the solubilization and compatibilization of the POSS ™ materials with existing plastics. This hybrid - organic/inorganic - composition along with their nano-size enables the POSS materials to occupy an enhanced property space relative to traditional organic (plastic) and inorganic (ceramic) materials, thereby dramatically enhancing the properties of existing plastics.



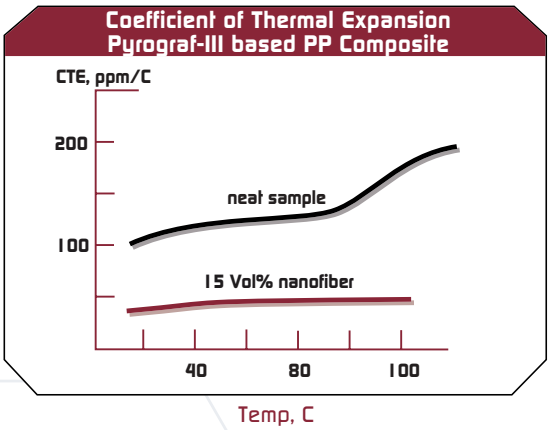
These well-defined POSS ™ molecules can be reactively compounded and/or nonreactively blended into a wide variety of chemical-based products. In addition, these nanochemicals can contain one or more covalently bonded reactive functionalities suitable for polymerization, grafting, surface bonding, or other transformations. The addition of POSS ™ materials to ordinary plastics can result in improved performance such as significantly increased heat distortion temperatures, reduced flammability, better oxidation resistance, and extended use temperature range, to name a few benefits. Since the POSS ™ materials are nano-sized and are smaller than the wavelength of light, they can be added to clear plastics without disturbing the optical clarity of the clear plastic.

For more information on POSS ™ see **www.hybridplastics.com**.

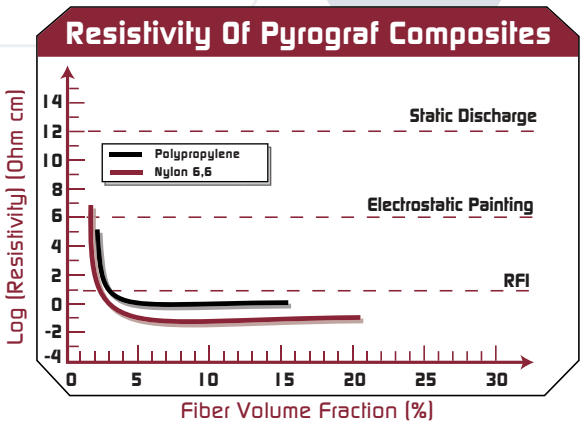
Pyrograf® III

An example of a family of Nanomaterials.

Pyrograf ® III is a family of novel graphitic nanofibers, which are produced by a Vapor Grown Carbon Fiber (VGCF) process. Pyrograf ® III is available from Applied Sciences' manufacturing division, Pyrograf ® Products, Inc. Pyrograf ® Products currently offers two types of nanofibers, PR-19 and PR-24. PR-19 has an average diameter of 200 nanometers and a Chemical Vapor Deposited (CVD) overcoat over the graphitic fiber core. PR-24 has an average diameter of about 100 nanometers and does not have a CVD overcoat. PR-24 is virtually graphitic and has the structure of a multi-walled carbon nanotube. Each type is available in three grades depending on the surface treatment. The surface treatment or lack thereof results in nanofibers of different surface energies and conductivities.



Pyrograf ® composite formulations enable the production of electrically conductive materials at significantly lower loadings than with carbon black (PAN or Pitch), carbon or steel fiber. Pyrograf ® conductive composites may be suitable for applications such as static discharge, electrostatic painting, and RF interference. Since the surface area and surface energy of the Pyrograf ® products can be tailored to match polymers, dispersions are easily accomplished to improve tensile strength while achieving the desired electrical properties. The Pyrograf ® unique process allows the placement of functional groups containing oxygen, nitrogen, and sulfur along the entire length of each nanofiber. Four fold increases in modulus and tensile strength have been achieved in rubber formulations by the addition of Pyrograf ® nanofibers.



For more information on Pyrograf ® III see **www.apsci.com**.

OHIO DEPARTMENT OF DEVELOPMENT

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