

Nanofiber Applications, Production, and Development

An overview of where nanofibers are going



MemPro Ceramics Corporation makes nanofiber materials for many markets and applications. The term “nanofiber” has a broad definition, but we believe that fibers having a diameter between 80-200 nanometers clearly fall into this category (a nanometer is one-billionth of a meter). Nanofibers are produced by a method called electrospinning, where different chemical solutions are “spun” from the liquid phase to the solid phase using electrical forces. Other methods of making nanofibers are being explored in research laboratories because the demand for nanofibers is expected to grow dramatically as the benefits become better understood.

The following is an overview of the potential applications of polymeric and inorganic nanofibers. Some of the links are from journal articles while others are papers written by scientists, newspapers, or magazines.

Energy

Over the past several years innovative companies have started to use nanomaterials to increase efficiency of batteries, photovoltaics, and fuel cells; nanofibers have played a significant role in the discovery of new ways to produce, capture, and store energy.

- **Batteries** <http://www.ntcresearch.org/pdf-rpts/AnRp09/M09-NS01-A9.pdf>
- **Photovoltaic cells** <http://ceramics.org/ceramictechtoday/materials-innovations/cadmium-oxide-nanofibers-show-better-performance-in-photovoltaic-cells/>
- **Polymer electrolytes or separators for batteries** <http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=ESLEF600001000000700A159000001&idtype=cvips&gifs=yes&ref=no>
- **Fuel cells** <http://www.springerlink.com/content/g60028p861604838/>
- **Lighting** <http://www.techbites.com/201002242166/myblog/articles/z001d-rti-international-uses-nanofibers-to-produce-efficient-eco-friendly-lighting.html>
- **Ultraviolet sensors** http://www.mrs.org/s_mrs/sec_subscribe.asp?CID=9127&DID=196193&action=detail
- **Supercapacitors** <http://www.krf.or.kr/downgood/2003/09/2003090001.pdf>
- **Power generation** - To reduce carbon emissions from fossil fuel combustion.

Engine Exhaust

Using catalyzed ceramic nanofibers to clean emissions from fossil fuel burning engines has been MemPro's focus for two years. With new EPA regulations passing each year, companies want to find low cost solutions to meet new NOx, CO, and HC (hydrocarbon) emissions standards.

- **Small engines** - lawnmowers, power equipment
- **Recreational boating**
- **Motorcycles**
- **Locomotives**
- **Large ships**
- **Power generators**
- **Construction equipment**
- **Agricultural equipment**
- **Heavy duty vehicles**
- **Automotives**
- **OEM**

Protective materials

The non-wovens industry has accepted that nanofiber materials can be used to help protect against biological and chemical agents.

- **Sound absorption materials** http://www.ustarch.sav.sk/ustarch/index.php?option=com_content&task=view&id=387&Itemid=32
- **Chemical and biological warfare protective clothing** <http://www.jeffjournal.org/papers/Volume2/Gibson.pdf>
- **Sensors for the detection of chemical agents** <http://pubs.acs.org/doi/abs/10.1021/ed085p1102>

Textile

Nanofibers have been used in clothing for many years for their thermal and strain-proof properties. Recently, the use of nanofibers in clothing has been studied for energy harvesting and conductive properties.

- **Breathable & waterproof materials** <http://dspace.lib.fcu.edu.tw/bitstream/2377/3929/1/ce05atc902007000053.pdf>
- **Napkins with nanofibers containing antibodies** http://medgadget.com/archives/2006/09/put_your_virusb.html
- **Conductive cotton for sensing fabrics** <http://www.azonano.com/news.asp?newsID=16344>
- **Energy harvesting clothing** <http://www.greenerdesign.com/news/2010/02/17/nanofibers-developed-energy-producing-clothes>
http://www.pcworld.com/article/189750/nanofiber_batteries_turn_movement_into_power.html

Filtration

The filtration industry uses nanofibers in particle filters for air and gas, where collection of very small particles is necessary. Catalyzed ceramic nanofibers can be used in filters to help convert noxious gases for applications such as furnaces and power plants.

- **HVAC filters** http://weldingdesign.com/safety-regulatory/air_filters_1108/
- **NOx control** - Reduction of hazardous gases from industrial, commercial and home furnaces.
- **HEPA and ULPA filters** <http://www.donaldson.com/en/filtermedia/support/datalibrary/052022.pdf>
- **Chemical warfare defense** <http://www.nanowerk.com/spotlight/spotid=555.php>
- **Oil filters** <http://www.amsoil.com/storefront/eao.aspx>
- **Food & beverage** http://www.epa.gov/ncer/sbir/success/pdf/espin_success.pdf
- **Power generation** - See **Energy** section above

Catalysts

Ceramic nanofibers increase surface area of catalysts by decreasing catalyst particle sizes. The benefits of using catalyzed ceramic nanofibers are (1) increase in surface area of catalyst material and (2) increased performance of catalysts.

- **Catalysts that kill cancer cells** <http://www.azonano.com/news.asp?NewsID=15920>
- **Chemicals** - Key players in chemical and catalyst markets are interested in optimal use of catalytic metals that are costly and in limited supply. Control of catalyst loss improves product quality especially in fine chemicals and pharmaceuticals.

Coatings

Ceramic nanofiber material can be used to strengthen paints and coatings. Other constituents can be added to nanofiber materials to add protective and thermal coatings, for example.

- **Paints** - To enhance durability and potentially improve visual characteristics.
- **Glass strengthening** <http://www.azonano.com/details.asp?ArticleId=2521>

Other

- **Light sail for space navigation** http://www.polymer.cn/Research/research_show1.asp?id=640
- **Aerospace** - Our technology partner, University of Akron, is already involved in advanced material research with agencies of the federal government.
- **Insulation** <http://nsrdec.natick.army.mil/media/fact/ss&t/NanoInsulation.htm>
- **Fire retardants** http://www.nanotech-now.com/news.cgi?story_id=31614
- **Flexible optical films**
- **Crack-free cements** <http://rip.trb.org/browse/dproject.asp?n=20258>
- **Explosion-proof materials** - Already in discussions with a customer in this market.

Medical

The use of nanofibers in the medical industry is relatively new, but medical advantages are achieved by using technologies that take advantage of particles at the molecular level.

- **Artificial organ components** http://bada.hb.se/bitstream/2320/4302/1/NTJ_08D.pdf
- **Tissue engineering** <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2426767/>
- **Organ implant materials** http://www.trnmag.com/Stories/2003/121703/Body_handles_nanofiber_better_121703.html
- **Drug delivery** <http://www.azonano.com/details.asp?ArticleID=114>
- **Wound dressings** http://www.polymer.cn/Research/research_show1.asp?id=640
- **Dental composites** <http://www.hindawi.com/journals/jnm/2008/840254.abs.html>
- **Medical textile materials & antimicrobial** http://snowman0.com/KyungHwa_PVA/jps_khh.pdf
- **Medical filters** <http://news.thomasnet.com/fullstory/828493>

The Future of Nanofibers

MemPro supports nanofiber research to better understand the characteristics, uses and production of nanofibers. MemPro shares the cost of research with the federal government (through grant funding) and with several global companies that do not compete directly in MemPro's markets. Twenty two researchers are involved in this effort. Discoveries believed to have commercial value are protected by patents and trade secret knowhow. A summary of current research follows.

Nanofiber production improvements

- **Comparison between nanofiber production technologies**
- **Understanding what causes fiber inconsistency in production**
- **Investigation of weak points in continuous nanofibers during production**
- **Characterizing nanofibers during production (quality assurance)**
- **Electrospinning of unique polymers**
- **Optimizing a scalable nanofiber production method**
- **Production of microfiber and nanofiber composites**
- **Addressing health and safety concerns in production and use of ceramic fibers**

Ceramic nanofiber development

- **Ceramic filters as catalyst and catalyst support structures**
- **Improved support structures for ceramic nanofibers**
- **Understanding ceramic nanofibers with uncommon electrical and catalytic properties**
- **Understanding the effect of varying diameters of fibers in catalytic converter applications**
- **Developing a computer model to predict performance in hot gas filtration**

Filter applications

- **Improving performance of coalescing filters**
- **Investigating new fiber media**
- **Understanding oil-water separation**

New applications

- **Discovering nanofibers that do not absorb water (super-hydrophobic fibers)**
- **Understanding the benefits of nanofiber mats**
- **Understanding the internal structure of nanofibers**
- **Developing implantable medical devices**

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For more information, please visit www.mempro.com and www.ceramicnanofibers.com or call (330)867-2222.

Email: inquiry@mempro.com