UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio Summer 2002

Directorate Develops Cost-Effective Air Sparged Hydrocyclone Technology Treatment

Researchers at the Air Force Research Laboratory's Materials and Manufacturing Directorate are developing cost-effective technologies to treat waste streams that contain emulsified petroleum-based substances such as fuels, oils and greases. The timesaving technologies can also be used to treat fire-fighting chemicals, such as Aqueous Film Forming Foam (AFFF) that is used to suppress combustible and flammable liquid fuel fires.

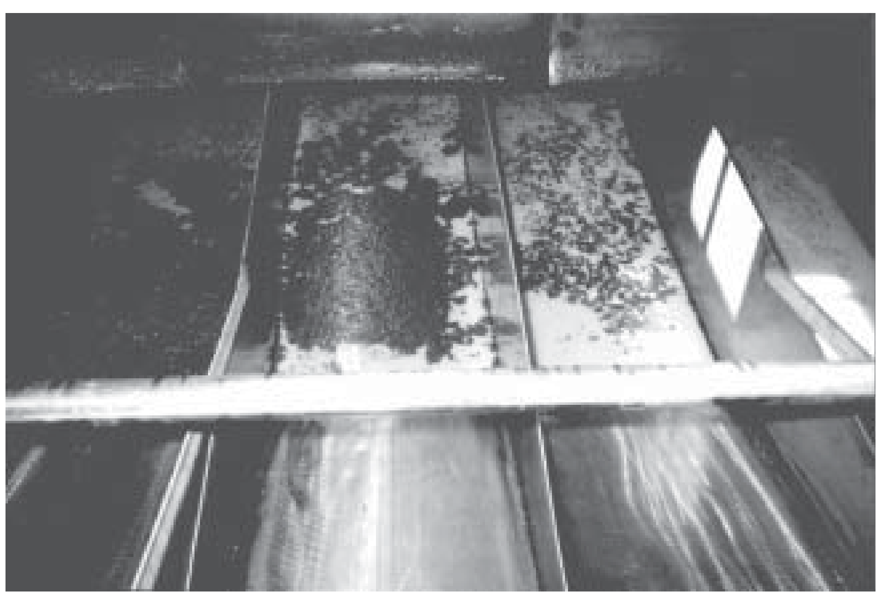
Many Department of Defense activities create waste streams from operations such as motor pool and aircraft wash racks, fuel tank cleaning operations, storm drains and fire fighter training. To ensure optimal waste streams management, researchers have evaluated several different treatments, including biological treatment, reverse osmosis and other physical and chemical removal methods. The most effective treatment system they have found is Air-Sparged Hydrocyclone (ASH) Technology, which was developed through collaborative research between the Air Force Research Laboratory, the Naval Facilities Engineering Service Center and the contractor, Kemco Systems, Inc.

Air Force researchers expect this technology will be a valuable tool in treating a variety of DoD generated waste streams where prior alternative treatment methods were non-existent, ineffective or extremely costly. Until now, solutions to wastewater challenges included "pump and treat," where a contractor takes the waste stream away at a significant cost to the military. Another solution was sending a small amount (due to the high toxicity and foaming characteristics of AFFF) to the industrial wastewater treatment plant each day. However, installations using this method generate more than they can send out each day, making this a larger problem as time passes.

Anxious to test the ASH technology, researchers developed a field test/demonstration project to validate the effectiveness of the ASH system at removing emulsified fuels, oil and grease, and AFFF from waste streams generated at nine DoD sites. The objective of the project was to demonstrate the commercial viability of the system, and to allow an audience to witness the operation of the technology, and to open doors for transfer of the technology to other DoD agencies and industry.

The ASH system works by combining flotation principles with the separation characteristics of a hydrocyclone, which separates fuel, oil and grease from water. In the case of fine particles and oil removal, the ASH system improves the ability of fine particles and oil droplets to float. First, a strong centrifugal force field is developed, which increases the inertia of fine hydrophobic particles and oil droplets. Second, a high-speed swirl flow exerts considerable shear force at a porous wall. When air is introduced through the extremely fine pores in this wall, numerous small air bubbles attach to the particles and oil droplets. When the bubble and particle or droplet are attached, they are transported a short distance and are removed from the water. When used in the removal of AFFF or any other foam-generating compound, the ASH system uses the compound's own foam-forming capabilities to strip it from water. These compounds are comprised of surface-active substances that concentrate where air and water interface to generate stable foams. The ASH's uniquely controlled aeration and flow control process effectively separates the AFFF compound from water.

During the demonstration, success of the system was determined by comparing the post-treatment concentrations of fuel, oil and grease, total suspended solids, and AFFF to influent (continued on page 2)



Removal of oil and grease from emulsified waste stream in ASH clarifiers

Technology Transferred from ML Project Results in Innovative Product Award

A product developed as a result of a contract with the Air Force Research Laboratory (AFRL) was recently recognized as one of the most innovative products of the year.

The product is a Crystal-Scan Laser Beam Multimeter, developed by Beam Corporation, of Oviedo, Fla. The technology used to create this product was developed under a Small Business Innovation Research (SBIR) project with Beam Corporation and AFRL's Materials and Manufacturing Directorate (ML).

Each year, Laurin Publishing's *Photonics Spectra* magazine recognizes what they consider to be the 25 most technically innovative products of the year, by presenting them the Photonics Circle of Excellence Award. The technology used to create the multimeter, which uses a light-sensitive liquid crystal active material, was developed under the "Photosensitive Liquid Crystals, Next Generation Materials for Dynamic Holography and Electro Optics" project.

For the last 10 years, Dr. Thomas Cooper, a researcher with ML's Survivability and Sensor Materials Division, made strides towards discovering a material whose optical properties would change upon light adaptation. During the project, researchers from the directorate and Beam researched, identified and developed a sensitive, highly efficient liquid crystal material that allows the manipulation of laser radiation and the characterization of laser beam shapes.

Using this same material, several technology transfer opportunities are possible, which will benefit the military, industry and the medical community. Optical devices such as liquid crystal optical components, all-optical-beam quality meters, optical laser beam power meters, diffractive optics, and handheld nonlinear optical devices will all benefit from this technology. "From this SBIR, we've been able to develop a first-rate liquid crystal technology," said Cooper. "What started with in-house basic science has developed into a useful application. This SBIR was imperative to finding useful answers about these next generation materials."

The technology was transferred and used in the Crystal-Scan Laser Beam Multimeter, which uses a 50-micrometer layer of nonlinear optical liquid crystal material, sandwiched between two pieces of glass. The optical properties of the liquid crystal material make it sensitive to the power density of an incident laser. When this sandwiched liquid crystal "cell" is placed at the focal point of a laser beam, a ring pattern is formed. The ring pattern can be observed visually on an observation screen, or directly through a camera. By comparing the pattern of the beam, both with and without the cell, beam profiles and information about the laser can be calculated by a computer algorithm.

For 14 years, these annual awards have recognized enterprising companies and individuals who have pushed the limits of technology to develop new photonic products and processes. The 25 winning products are chosen by members of *Photonics Spectra's* Editorial Advisory Board, a panel of experts in a variety of technical disciplines, from hundreds of entries submitted from around the world. To be eligible for a 2001 award, the products had to be commercially available between Jun. 1, 2000, and May 31, 2001.

Beam Corporation's Crystal-Scan Laser Beam Multimeter.

The ceremony honoring the 2001 Photonics Circle of Excellence Award Winners took place Jan. 21, in San Jose, CA. The ceremony was held concurrently with SPIE's (Society of Photo Optical Instrumentation Engineers) Photonics West, America's largest commercial exhibition of optics, lasers, optoelectronic components and imaging technologies.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 02-054.

Air Sparged Hydrocyclone Technology

(continued from page 1)

concentrations and local discharge limits. In the absence of a regulatory limit of AFFF, a target value of under 50 parts per million (ppm) was used.

The ASH system consistently met its objectives of demonstrating and quantifying its ability to effectively and efficiently remove emulsified oil and grease, and AFFF from waste streams. The system resulted in an average removal rate greater than 87 percent and greater than 90 percent for oil and grease removal and AFFF removal, respectively. These results were achieved in streams that contained varying types and concentrations of contaminants, in streams that contained oil and grease only, AFFF only, and in streams that contained a combination of all contaminants.

These results were also achieved in cases of high AFFF concentration (over 500 ppm). A recirculation option was incorporated into the system allowing batch operation. In this fashion, wastewater can be processed multiple times until the desired effluent concentration is obtained.

In most cases, the concentrated sludge remaining from ASH processing was less than 10 percent of the original stream volume, and in many cases, lower than seven percent. Toxicity leaching tests conducted on this sludge reported that the sludge is classified as non-hazardous.

The predicted operating costs for the system are dependent on the specific contamination characteristics of the waste stream. The costs of operation during the DoD demonstrations ranged from $.17 per 1,000 gallons treated for AFFF treatment with no chemical treatment, to $2.54 per 1,000 gallons treated for extremely high oil and grease concentrations with chemical pre-treatment. The operating costs include the cost of consumables and utilities associated with the system.

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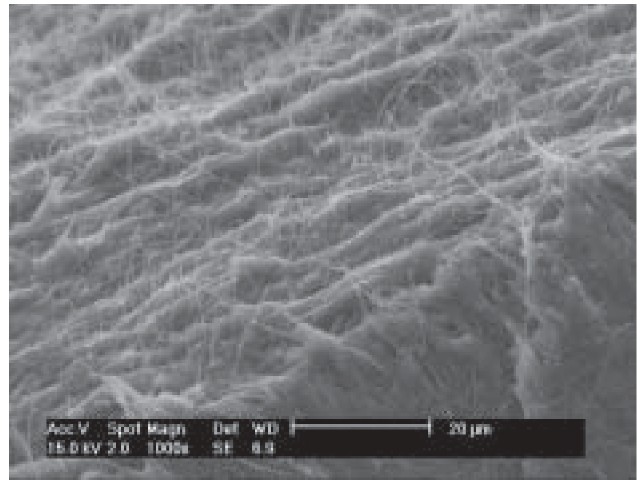
Nanotechnology Enables Development of Multifunctional Conductive Plastics and Aerospace Composites

Scientists and engineers at the Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/ML), have found a way to enhance the quality and performance of polymeric materials used to build military and commercial aerospace components.

Working with the University of Dayton Research Institute (UDRI), they discovered a way to tailor the electrical conductivity of many commodity polymers over a range of 10^{-6} S/cm (Siemens per centimeter) to 10^{2} S/cm, without impacting their intrinsic mechanical properties and processability. This offers the opportunity to use traditional polymers and processing techniques to produce materials suitable for electrostatic discharge and electromagnetic interference shielding applications.

Their new technology transforms almost any commodity polymer into a multifunctional material capable of carrying or dissipating significant electrical charge – an advancement offering tremendous promise throughout the space, aerospace, automotive, and chemical industries. The researchers achieved this technological advancement by controlled dispersion of specifically designed, highly electrically conductive, yet remarkably flexible multi-wall carbon nanotubes into the supporting polymer matrix. These nanotubes have the current carrying capacity of copper but with a comparatively much lower density.

The nanotubes used in the finished products are on the order of 50 to 150 nm in diameter with an aspect ratio (the ratio of their length to their diameter) of greater than 800. This high aspect ratio results in a much lower required filler content to achieve percolation (onset of conductivity) than traditional metal filled systems. As a matter of fact, the percolation threshold for these materials is less than one half of one percent by volume. The multi-wall nanotubes used in this process are available in ton quantities, which has allowed for affordable, realistic scale-up of the resultant nanocomposites.



Electron micrograph of typical silicon nanocomposite cross-section showing uniform distribution of a conductive carbon nanotube network.

The electrically conductive polymer nanocomposite materials, compared to conductive metal filled systems, offer substantial weight savings, flexibility, durability, low temperature processability, and tailored reproducible conductivity. They may be used to form conductive paints, coatings, caulks, sealants, adhesives, fibers, thin films, thick sheets and tubes as well as for large structural components electromagnetic interference shielding, electrostatic painting of panels, electrostatic discharge and opto-electronic device applications.

Of particular interest is the materials' enhanced high frequency absorption capability making it particularly well suited to the cable shielding industry. The materials' easy processability allows for co-extrusion for coaxial cables replacing the high weight braided metal shielding. The technology is ready for licensing and commercialization and is easily capable of scaling to large batch production.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 01-236.

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COMPLETED Contracts

- Novel Composite Materials For The Manufacture Of Functionally Graded Structures - F33615-99-C-5004
- Thermally And Electrically Conductive Adhesives For the F-22 Subarray Assembly - F33615-01-M-5009
- Novel and Automated Installation Methods For Aircraft Applique - F33615-01-M-5012
- High Performance Composite Materials - F33615-95-D-5029
- Novel High Performance Polymers - F33615-95-D-5044
- Poly Arylene Ether-Based, High Performance, Solvent Free Processing of Aircraft Canopies - F33615-98-C-5053
- Advanced Aircraft Corrosion Resistant Coating Systems - F33615-96-C-5078
- Hybrid Composites Manufacturing Technology Braiding/Filament Winding - F33615-98-C-5153
- A Remarkable Material For Advanced Ceramic Matrix Composite Propulsion Systems -F33615-98-C-5157
- Advanced Field Use Instrument For Nondestructive Evaluation Fatigue Damage Assessment - F33615-99-C-5201
- Improved Titanium Machining Process - F33615-01-M-5300
- Flow Optimized Repair Cycle (Force) - F33615-99-C-5307
- Development Of Optical Host Materials With High Laser Damage Thresholds - F33615-01-M-5413
- Next Generation Polymeric Optical Host Materials - F33615-01-M-5414
- Bulk Gallium Nitride Crystal Growth - F33615-00-C-5420
- Improved Surfaces For Silicon Carbide Epitaxy - F33615-97-C-5474
- Improved Surfaces For Silicon Carbide Epitaxy II - F33615-97-C-5483
- Removal Tools And Process For Low Observable Materials - F33615-01-M-5603
- Removal Tools And Process For Low Observable Materials - F33615-01-M-5604
- Ultraviolet Light Curing Materials For Field Level Composite Repair - F33615-01-M-5608
- Non-Metals Test And Evaluation - F33615-95-D-5616
- Nondestructive Evaluation Exploratory Development For Air Force Systems - F33615-97-C-5640
- Fullerene-Dendrimer Optical Limiters - F33615-01-M-5703
- Direct Fluorination Technology - F33615-92-C-5975

NEW Contracts

- Embedded Micro-Instrumentation For Health Monitoring - F33615-02-C-5013
- Advanced Case Materials - F33615-02-C-5014
- Advanced Materials And Processes For Monopropellant Chambers - F33615-02-C-5209
- Manufacturing Technology For Engine Rotor Life Extension - F33615-01-C-5302
- Lightweight Titanium Heat Exchangers - F33615-02-M-5322
- Active Photonic Crystals For Wave Division Multiplexing Applications - F33615-02-C-5400
- A Novel Approach To The Fabrication Of Polymer-Based Electro-Optic Devices and Subsystems On A Chip - F33615-02-M-5405
- Use Of Alternate Materials For Infrared Missile Domes - F33615-02-M-5408
- Hybrid Semi-Insulating Silicon Carbide Wafers - F33615-02-M-5409
- Epitaxial Ferro-Electric Thin Films For Electro-Optic Devices - F33615-02-M-5411
- Optimization Of Polymer Cladding Materials For Polymer-Based Electro-Optic Devices - F33615-02-M-5412
- Type-II InAs/GaSb Superlattice Detectors - F33615-02-M-5419
- Periodically Poled Stoichiometric Lithium Tantalate: A New Approach for A New Material - F33615-02-M-5420
- Novel Systems For Bulk Growth Of Semi-Insulating Silicon Carbide - F33615-02-M-5422
- Gallium Nitride Semi-Insulating Substrates - F33615-02-M-5423
- High Performance Fiber-Optic Depolarizer - F33615-02-M-5608
- Optimized Phased Array Hard Alpha Inclusion Detection - F33615-02-M-5610
- Nano Metal Oxide-Conductive Polymer Anti-Corrosion Coating for Aluminum - F33615-02-M-5611
- New High Durability Sol-Gel Surface Pre-Treatments - F33615-02-M-5612
- Engine Component Life Management Technology - F33615-02-C-5703
- Affordable Microelectromechanical Systems-Based Inertial Measurement Units For Missiles And Munitions - F33615-01-3-5705

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OFFICIAL BUSINESS

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