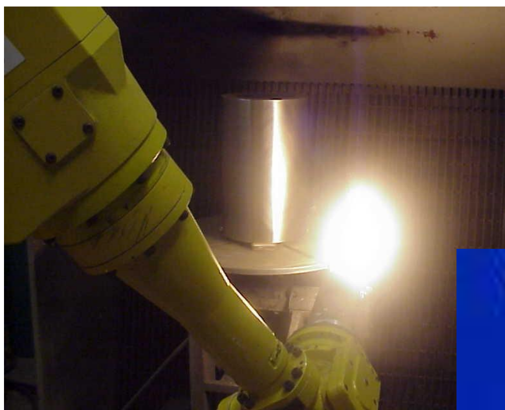
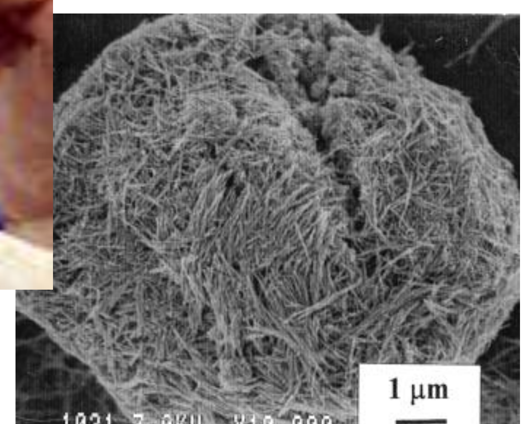
Inframat ® Corporation

NBCA Philadelphia
17 October, 2013





inframat®

Facilities

USA

151 Progress Dr., Manchester, CT 06042

China

Yizhuang (Beijing Economic and Technological Development Area)

1st floor A1, Zhong Hui Mansion
No. 3 Disheng Middle Rd., BDA, Beijing 100176

18,000 sq ft Facility – Manchester Inventory, Heavy Mfg, Lab

Beijing Sales Rep Facility

Highlights

Award Highlights

2001 **R&D Magazine - *R&D 100 Award* – Nanox™ 2613**
2002-2005 Deloitte & Touche Fast 50 Awards (Inframat)
2002-2003 Deloitte & Touche Fast 50 Awards (US Nanocorp)
2003 Deloitte & Touche Fast 500 Award (US Nanocorp)
2004 World Economic Forum – *Technology Pioneer* (Reisner)
2004 *Forbes* Magazine feature article (June 21)

"I think we've turned a corner":
James Hsiao, David Reisner and Danny Xiao.

Entrepreneurs

In Dust We Trust

A nanotech company starts small.

BY TOMAS KELLNER

THE OLD REDBRICK MILL ON RIVER ROAD IN Willington, Conn. recalls the textile factories that led American industry 200 years ago. Water from a bucolic pond drains into a sluice gate and rushes down a shallow millrace. A preserved power shaft still hangs from thick oak rafters.

Step inside, where a slight chemical odor pinches the nose, and witness a new kind of industrial revolution. A dozen researchers, speaking a medley of Asian accents, bustle between a bank of fume hoods, works in progress and box furnaces set in a 10,000-square-foot lab. In the middle of the floor a tattooed mechanic with a mullet assembles a piece of testing equipment. He and David Reisner, cofounder and chief executive of Inframat, are among the few Caucasians here—a small illustration of what you might call insourcing. "There just weren't enough [qualified Americans] around," Reisner says.

This is pretty specialized work. Some 30 men and women are developing nanostructured coating materials that vastly improve the mechanical features—durability and thermal properties, for instance—of parts made from conventional metals like steel and bronze. Working with compounds whose grains are as small as ten-billionths of a meter across, the engineers are toughening propeller shafts on Navy minesweepers as well as tooth implants and artificial joints. Inframat and its sister company, US Nanocorp (which builds battery and fuel-cell nanomaterials), are idea labs. In 2003 the companies pulled in $3 million in revenue, only 10% from commercial sales. The bulk was government research money, the main source of the $20 million in grants and contracts Reisner has sucked up since 1996, when he started out, from the likes of the Navy, NASA, the National Institutes of Health and other agencies. Private capital abhors abstruse products that can take years to reach the market. Besides, he says, "We would have had to give away half the company for a few hundred thousand dollars."

Reisner pushes his folks to conduct research with commercial potential, then draft grant proposals. The vice president of R&D corrects their grammar and sends off the requests. "[Paid] research gives you the freedom to try stuff out," he says. Hundreds of old proposals are crammed in white cardboard boxes inside Reisner's office at the nearby Farmington headquarters. Two out of ten grant applications, he says, are approved.

The next step is selling discoveries to commercial clients. Last year materials scientist H. Amy Chen landed a $750,000 grant from the U.S. Air Force for water filtration research. She found that nanofibers made from manganese oxide can be synthesized into bird's-nest-like matrices with high surface areas that trap most contaminants, including lead and arsenic. Today she's working with Omnipure to build manganese oxide filters for kitchen taps. Xinging Ma, a materials scientist whom Reisner recruited from the Sorbonne in Paris, is working on a project with United Technologies' Pratt & Whitney, spraying jet engine parts with Inframat's thermal barrier nanocoatings; the material, zirconia dust, was originally developed for the Navy. Ma relies on a patent in his own name to turn zirconia into a solution, applying it with a rented plasma gun burning at 30,000 degrees Fahrenheit. The coat behaves like a thermal blanket, protecting parts such as turbine blades from a meltdown. That in turn allows an experimental jet to run hotter, boosting efficiency from 400 cycles to 1,200 cycles. So far the company's research has yielded 21 patents but no solid commercial deals. "I espouse a very Darwinian approach," says Reisner. "You throw things against the wall and see what sticks."

Reisner launched this business eight years ago with help from two University of Connecticut materials scientists, T. Danny Xiao and Peter Strutt, and onetime dean of the business school at Southern Connecticut State University James Hsiao. Reisner, 49, joined IBM in San Jose, Calif. after receiving a Ph.D. from MIT in physical chemistry. While working for

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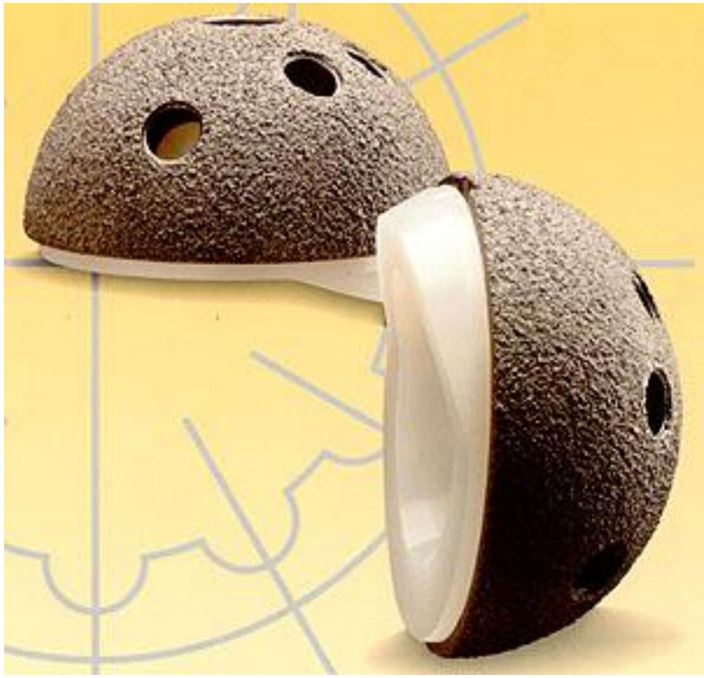
Collaboration Highlights

ARCI-Inframat SPPS Centre Inaugural Ceremony on January 17, 2009 in Hyderabad, India. ARCI is the International Advanced Research Centre for Powder Metallurgy & New Materials.

Collaboration Highlights

“Big-5” orthopedics company engages Inframat (2007) to develop dense ceramic nanocoatings for hip/knee joints to increase service life from 12 to 25 years.

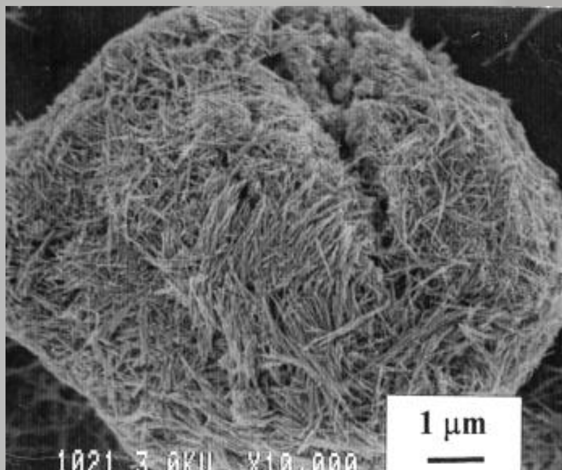


room of a 1950s science geek—wood-paneled walls decorated with posters titled "Metabolic Pathways" and "The Molecular Pharmacopoeia"—the startup company's president and chairman, Anil Diwan, will tell you that he has developed a "game-changing technology" for virus-killing drugs.

Using nanotechnology—the science of the very, very small—Diwan makes drugs that seek out and destroy viruses the way antibiotics attack bacteria, he explains. Tests of his drugs for HIV, flu and severe pinkeye show that "there is nothing to match it anywhere in the world," he claims. "In nanomedicine, we are prob-

Core Technologies

Core Enabling Technologies



Low-Cost Wet Chemistry Synthesis of Nanomaterials

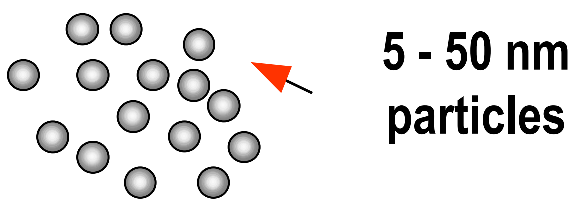
Thermal Spray and Electrodeposition of Nanostructured Coatings

- ***$25 Million Customer Financing (NGI)***
- ***24 Patents Issued, >30 Pending***

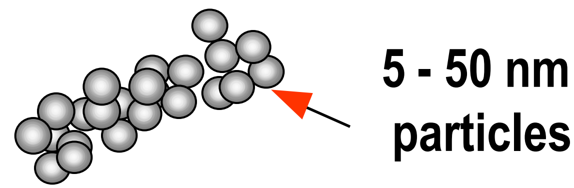
Thermal Spray Nanocoatings

inframat®

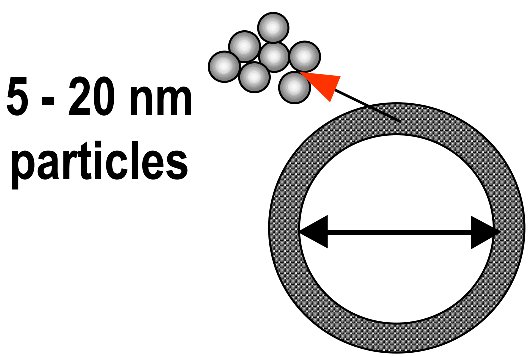
Inframat's Nanopowder Feedstock Precursors & Reconstitution



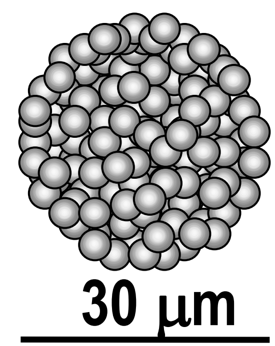
non-agglomerated



loosely agglomerated

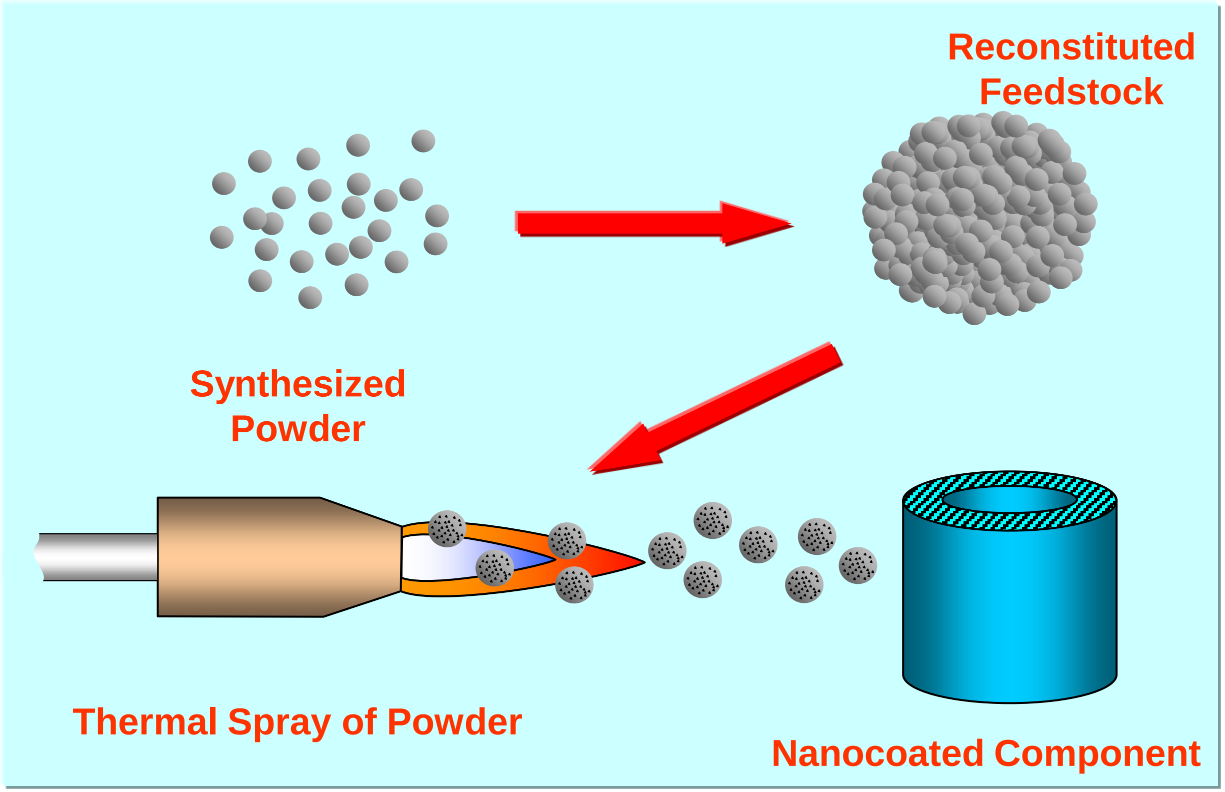


hollow shell agglomerates

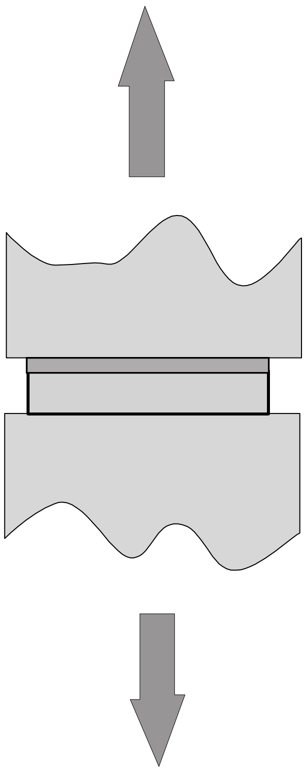


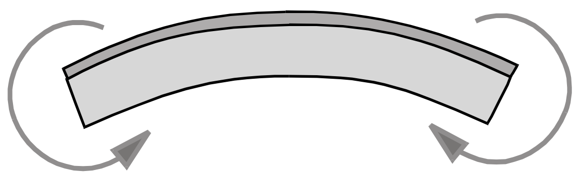
reconstituted sprayable form

Thermal Spray of Nanopowder Feedstocks

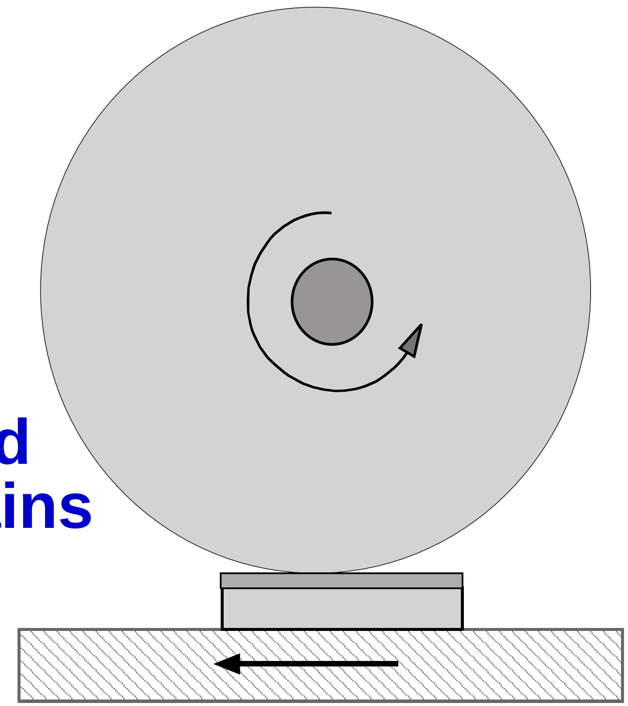


Nanox™ S2600S series (alumina based)





Ability to withstand higher bending strains



Increased bond strength

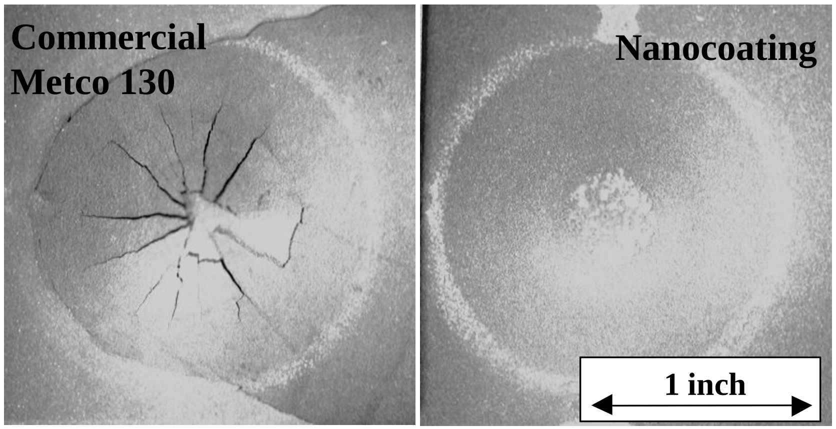
Conventional: ~ 2,000 psi

Nanostructured: ~ 8,000 psi

Improved grindability

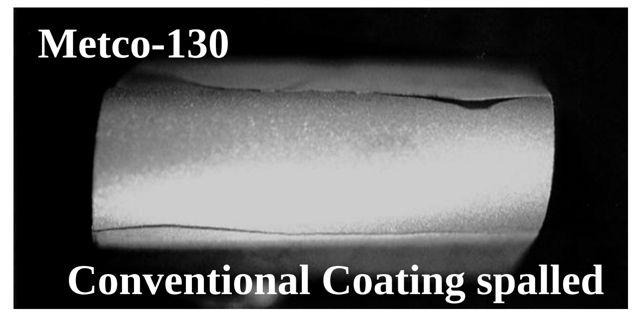
Superior Properties:
Cup Test, Bend Test, Abrasive Wear

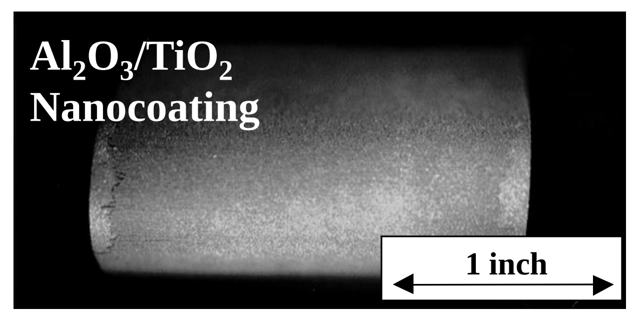
Cup Test: Superior Adhesion and Crack Resistance



Nanocoating has no cracks in Cup test

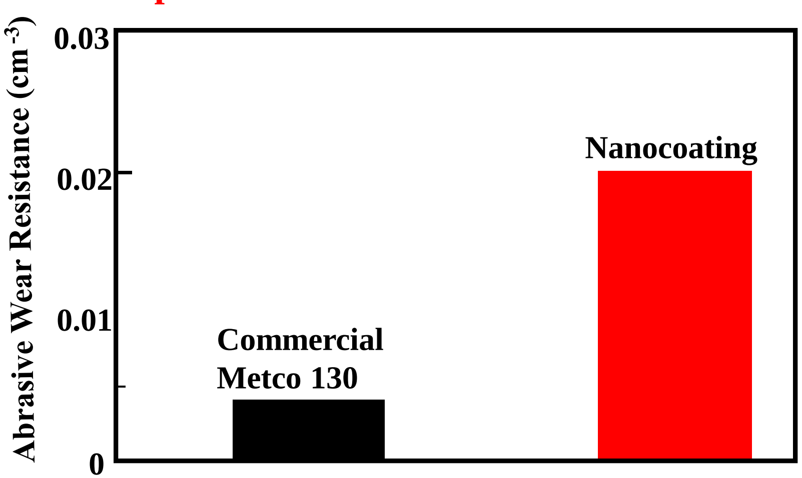
Bend Test: Superior Adhesion, Toughness and Crack resistance





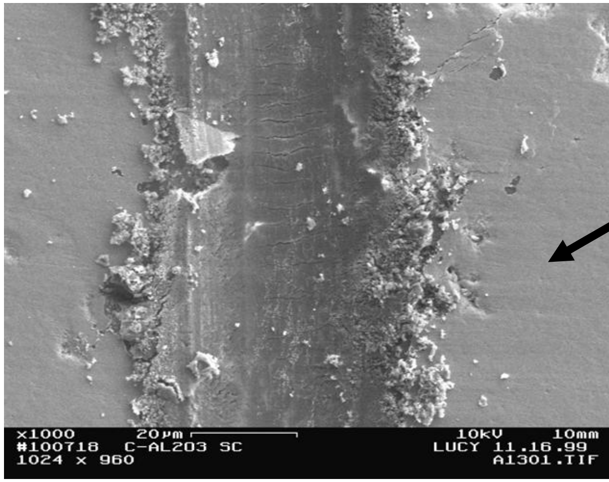
Nanocoating has no spallation

Superior Abrasive Wear Resistance



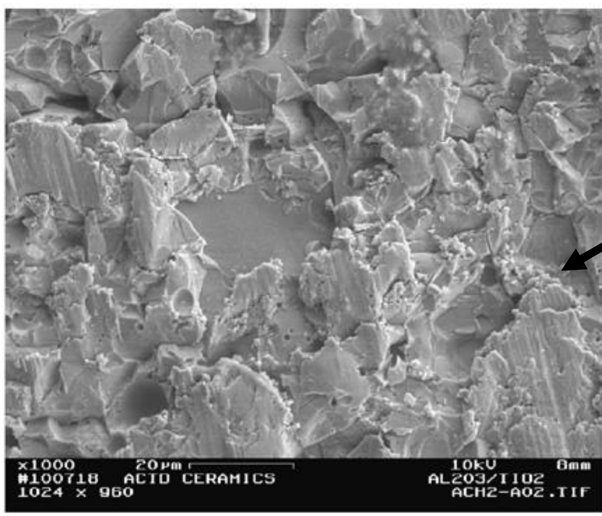
Nanocoating has increased wear resistance

Wear Surfaces of Al_2O_3/TiO_2 Nanocoatings



Metco 130

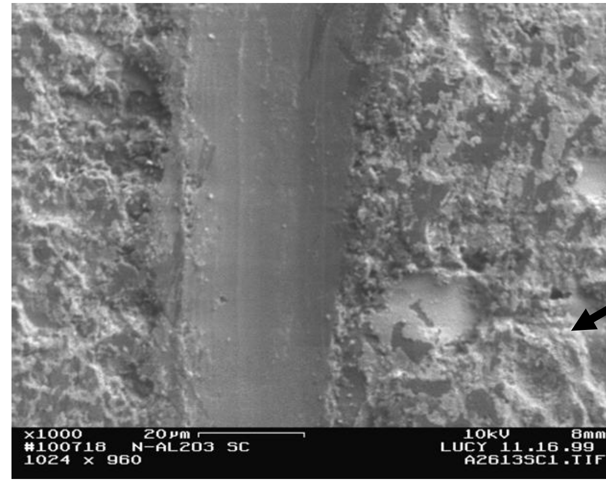
Scratched surface



Metco 130

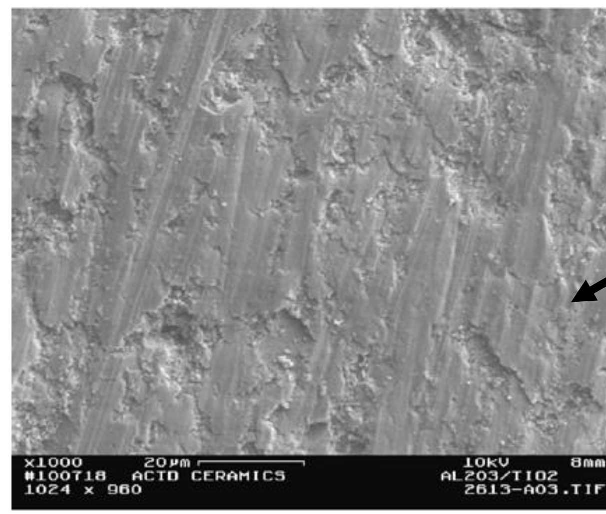
Abraded surface

SEM micrograph of worn surface of Metco 130 coating. Note: large "plate like" pieces were removed by wear resulting in grain "pull-out."



Al_2O_3/TiO_2 Nanocoating

Scratched surface



Al_2O_3/TiO_2 Nanocoating

Abraded surface

SEM micrograph of worn surface of Al_2O_3/ TiO_2 nanocoating. Smaller pieces were removed resulting in polishing of the coating surface.

Inframat ® has Real Nano Products !

Nanox™ – Ceramic Nanocoating

"used in 150 applications…." U.S. Navy

90º bend

R&D 100

Wear and Impact Resistance, Ductility

Navy Certified – MIL–STD–1687a

Commercial Nanocoatings family

Nanox™, Nanalloy ®, Infralloy™

Navy - dry dock evaluation of minesweeper propulsion shafts

Conventional ceramic coatings show scoring (above)

Ceramic nanocoatings – no scoring (5 years service)

MARITIME TECHNOLOGY

The Newsletter of the Maritime Technology Alliance *April 2005 * Vol. 3 Number 1*

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MARITIME TECHNOLOGY ALLIANCE

The Maritime Technology Alliance Activities

This newsletter opens the third year of MTA newsletter publication and is the second edition presented in an expanded eight-page format. Featured in this edition are articles that outline the **Technology Transfer** process at the Naval Surface Warfare Center (NSWC) Carderock Division, introduce the **Maritime Institute of Technology and Graduate Studies** (MITAGS) at Linthicum, Maryland, describe the DD(X) Land Based Test Site (LBTS) in Philadelphia, Pennsylvania, and highlight the Office of Naval Research (ONR) and Naval Sea Systems Command (NAVSEA) **Center for Innovation in Ship Design** (CISD). An article outlining MTA membership benefits completes this edition.

These articles cover a wide range of maritime interests. Industrial and academic activities seeking to tap into the wealth of maritime technology available at the NSWC Carderock Division should find the Technology Transfer article of value. MITAGS offers a breadth of support services for maritime activities, including education and training and vast well-equipped modern meeting and conference facilities. The DD(X) LBTS at the NSWC Carderock Division Philadelphia base is an extensive facility involving numerous organizations and equipment manufacturers. Full-up system testing is planned for the latter half of 2005. The CISD, in support of the US Navy's National Naval Responsibility Initiative for Naval Engineering, offers collaborative activities involving naval/marine oriented faculty, students, government and industry personnel.

In the past six months, MTA has continued to promote the maritime interests of Maryland and surrounding area.

A sampling of such activities follows:
The **SMART** (Strengthening the Mid-Atlantic Region for Tomorrow) Initiative coordinates regional economic and national objectives of Maryland, Delaware, New Jersey and Pennsylvania. Ivan Caplan, Vice President of MTA, chairs the SMART Maritime Subgroup (SMSG). In meetings held in the latter part of 2004, the SMSG finalized its charter, developed a set of objectives and established its concept of operations. The next meeting of the working group is envisioned for March 2005. If your organization is interested in participating in or learning more about the working group, please contact Ivan Caplan at ILCaplan@comcast.net.

MTA continued to participate as a member of the Governor of Maryland, Robert L. Ehrlich's **Maryland Military Installation Strategic Planning Council** organized to ensure that the capabilities and value of Maryland's military bases are fully understood and appreciated and that they are adequately supported to deliver their essential services and products. Three meetings of the Council were held during this period at which MTA delivered presentations outlining the capabilities and status of NSWC Carderock Division.

On November 30th, MTA's President, Richard E. Metrey, briefed Maryland Congressional delegation staff members on Capitol Hill who were convened to examine the issues and concerns facing the Maryland military bases in the forthcoming 2005 round of Base Realignment and Closure (BRAC).

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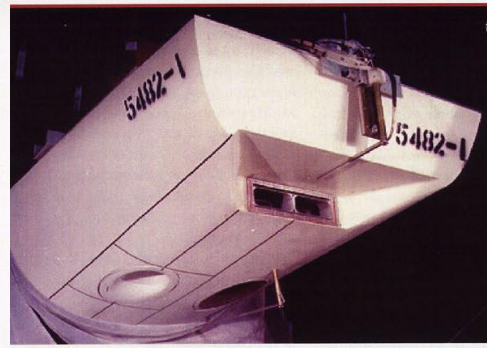

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One design solution is the **VMP** (Vertical Motor Propulsor), which was developed at Carderock in the mid 90s for a monohull displacement ship. The VMP uses a mixed flow pump and a nearly vertical inlet. It has a very short flow passage for minimum flow losses and is an enabler for electric drive propulsion. VMP takes the form of a mixed flow pump with a very steep intake and a volute. The volute discharge is in a generally horizontal direction and is connected by a horizontal duct to the transom of the ship where the flow is discharged through the nozzle. A schematic of a model scale DDG 51 with modified stern and the VMP inlet and nozzle installation are shown in the figures.

A major challenge for the development of VMP includes development of an analytical design methodology for efficient intake design and the development of a novel underwater steering and backing mechanism. Three government patents were granted for the VMP concept. The VMP was demonstrated through model scale testing that it is comparable in powering performance as compared with the conventional screw propeller and is superior in maneuvering and backing performances. Furthermore, VMP was also predicted to be more survivable compared to conventional propulsion. Presently, there are three additional invention disclosures associated with this research area that are expected to be patented.

High Performance Coatings for Corrosion and Wear

Abrasive debris trapped in the shaft housing staves of mine countermeasure ships eventually score the shafts, limiting shaft life to about one year. No existing coating was available which could survive in the environment, protect the shaft, and not create galvanic corrosion problems. The cost of recurring repair was averaging $1.5M every 18 months for this US Navy ship class to dry-dock, remove and refit, and weld repair damaged shafting. The solution was to develop a revolutionary **ceramic nanocomposite coating**. Coated shafts were tested in service on four ships. Inspection revealed an intact, biological growth-free coating with no evident scoring after 3 years service. This highly tenacious, functional coating has other application potential to resolve wear and/or combined wear-corrosion issues.

This project is highly demonstrative of what value is added by employing efficient teaming from development through application when end-use application is the primary focus.

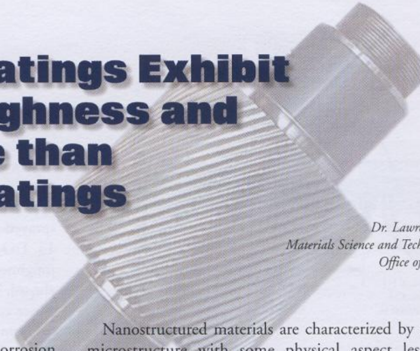
Thermal Spray Nanocoatings

Nanox^{TM} S2600S series (Al_2O_3 - TiO_2)

Ductility Unprecedented for ceramics! -
90° Substrate Bend

inframat®

Nanoceramic Coatings Exhibit Much Higher Toughness and Wear Resistance than Conventional Coatings



Dr. Lawrence T. Kabacoff
Materials Science and Technology Division
Office of Naval Research

Introduction

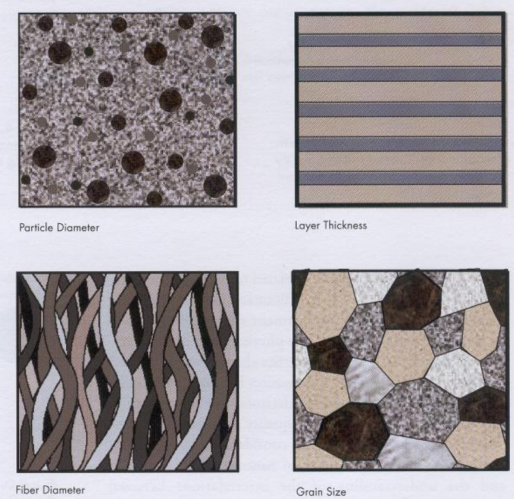
Modifying material surfaces to enhance wear and corrosion resistance is a common practice for both military and commercial applications. Electrodeposited hard chrome is one of the most widely used protective coatings. Ceramic coatings, both single phase and composite types, are also common and they are frequently applied using plasma spray. In this process, the coating material (usually in the form of a powder) is injected into a plasma stream where it is heated and accelerated toward the substrate surface. After impacting the surface the ceramic rapidly cools thus forming a coating layer.

Both hard chrome and ceramic coatings have serious deficiencies that can limit their use. Chrome electroplating uses closely regulated hazardous materials. Compliance with the various environmental safety regulations has made hard chrome increasingly expensive to use. Plasma-sprayed ceramic coatings are somewhat less expensive than chrome (when clean up costs are included), but are generally brittle and have limited success adhering to substrates, which is also a problem for hard chrome. The need for better coating materials has been recognized and considerable effort has recently gone into finding replacements.

Over the last five years, a consortium of companies, universities and Navy personnel have been developing a new generation of wear resistant "nanostructured" ceramic coatings. The consortium is lead by Inframat, Inc. and the University of Connecticut, and team members include the A&A Company, Rutgers University, Stevens Institute of Technology, the Naval Surface Warfare Center (Carderock Division) and Puget Sound Naval Shipyard. It is funded by the Office of Naval Research and its objective has been to achieve mechanical and wear properties unobtainable from more conventional materials (i.e. materials with structural aspects at the micron scale or larger).

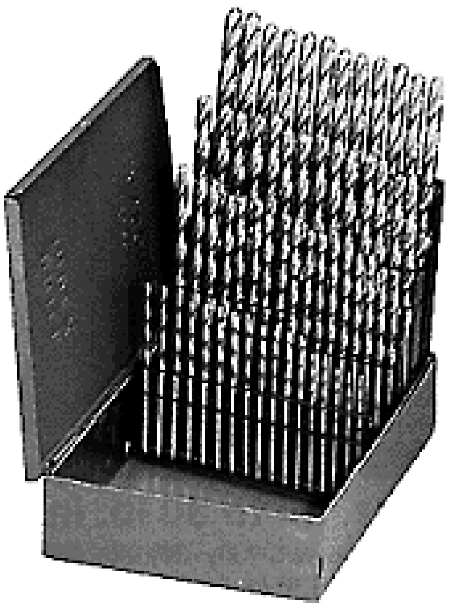
Nanostructured materials are characterized by an ultra-fine microstructure with some physical aspect less than 100 nanometers in size. This feature can be grain size, particle or fiber diameter, or layer thickness (Figure 1). There are two reasons why reducing the scale of a material's microstructure can significantly alter its properties. First, as grain size gets smaller, the proportion of atoms at grain boundaries or on surfaces increases rapidly. In a polycrystalline material with a grain size of 10nm, as many as 50% of its atoms are at grain boundaries, resulting in a material with properties far different than nor-

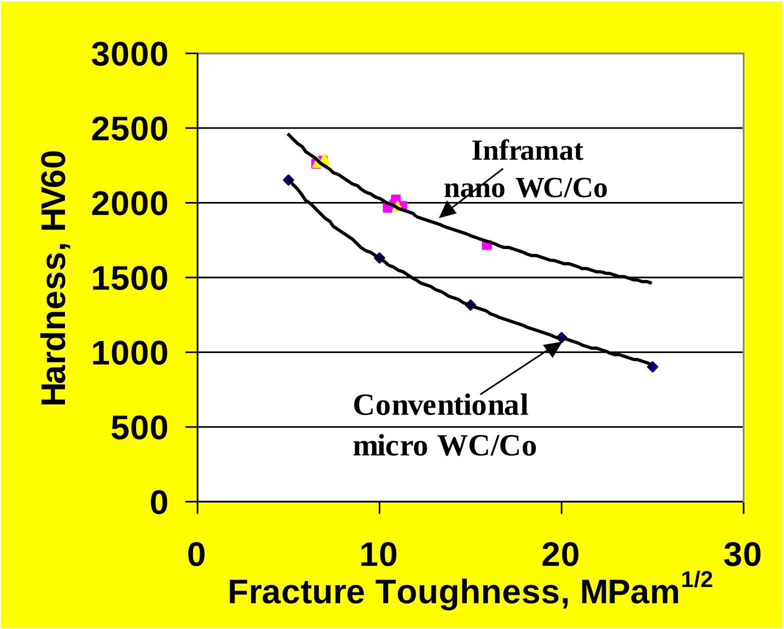
Figure 1. Nanostructured Materials are Characterized by the Inclusion of One or More Types of Features with Dimension Below 100 Nanometers



inframat®

We all can benefit from Nano Coatings !



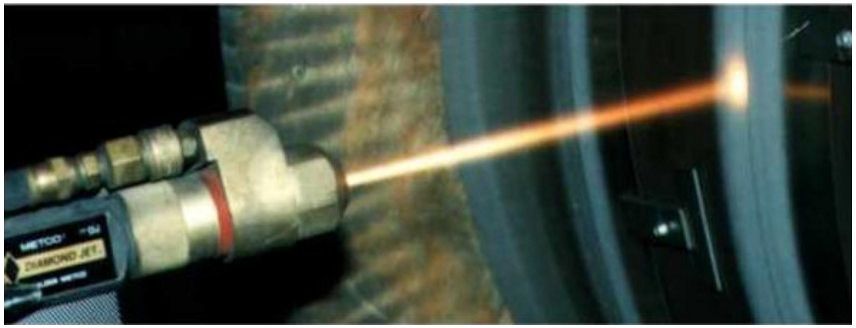


When was the last time you broke a drill bit?

Thermal Spray Feedstock Production

Spray Driers, Belt Furnaces, and Rotary Furnaces used for volume production

Gear & Roller Application



- Printing roller
- Steel mill sink rollers
- Gear, seat, shoulder
- Piston, pump, valve

- High hardness >1,200
- Low stress
- High strain tolerance
- Strong bond strength
- Homogeneity
- Good finishing

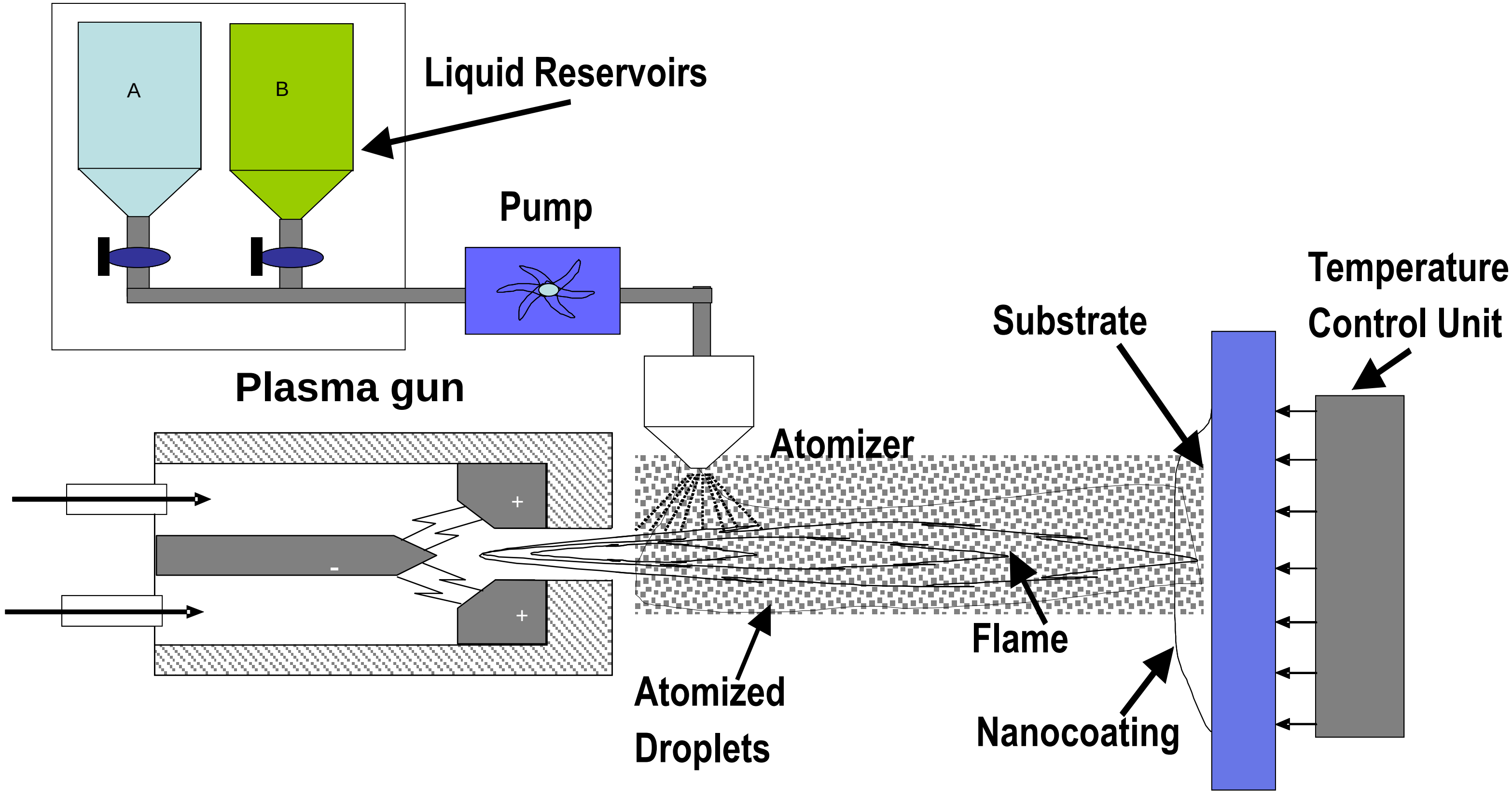
Inframat's China Team with coated sink roller

Into the Future, What's Next ?

Inframat ® has a revolutionary approach to thermal spray coatings using a Solution Plasma Spray (SPS™) process

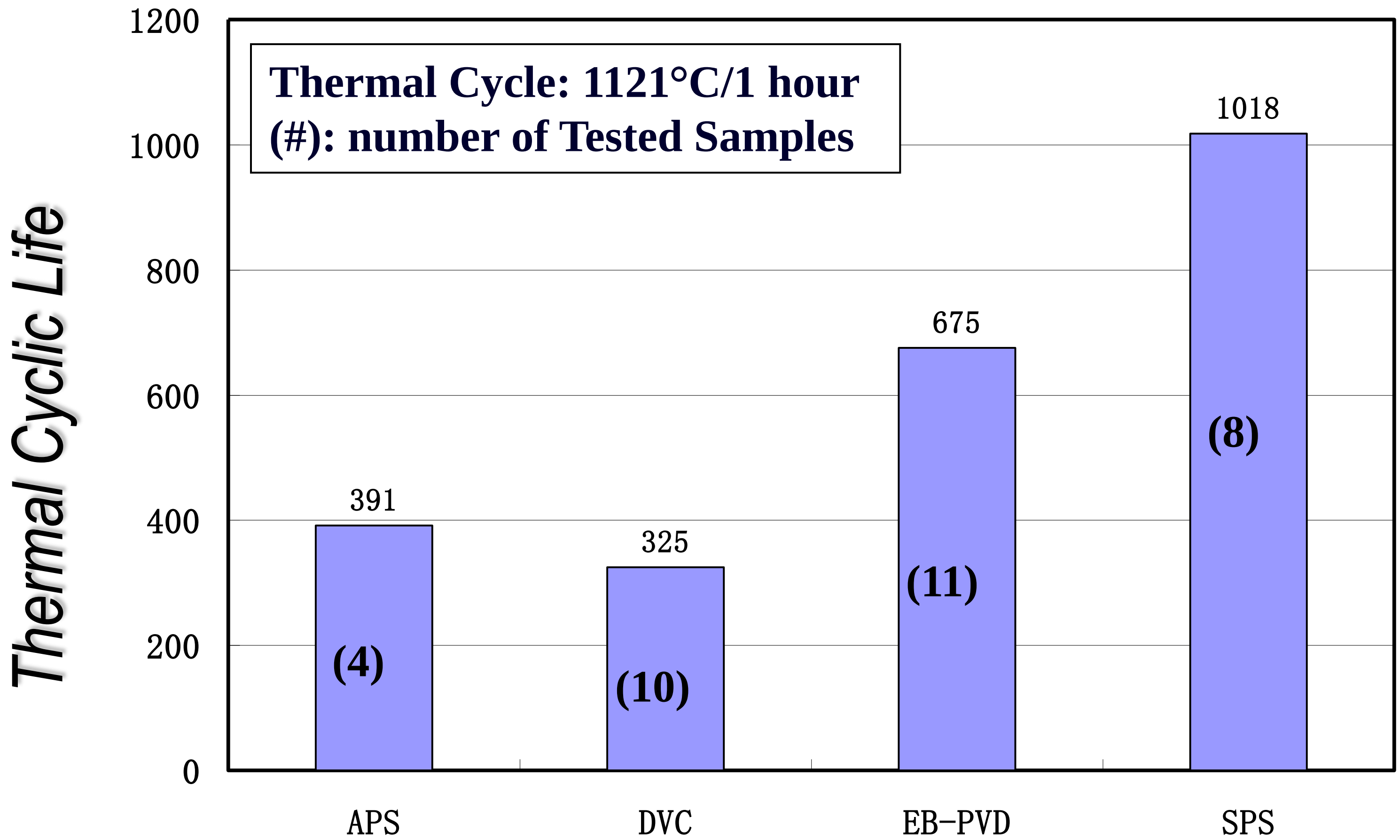
- *Replace Powder with Solution*

Thermal Spray Nanocoatings - Solution Plasma Spray Process

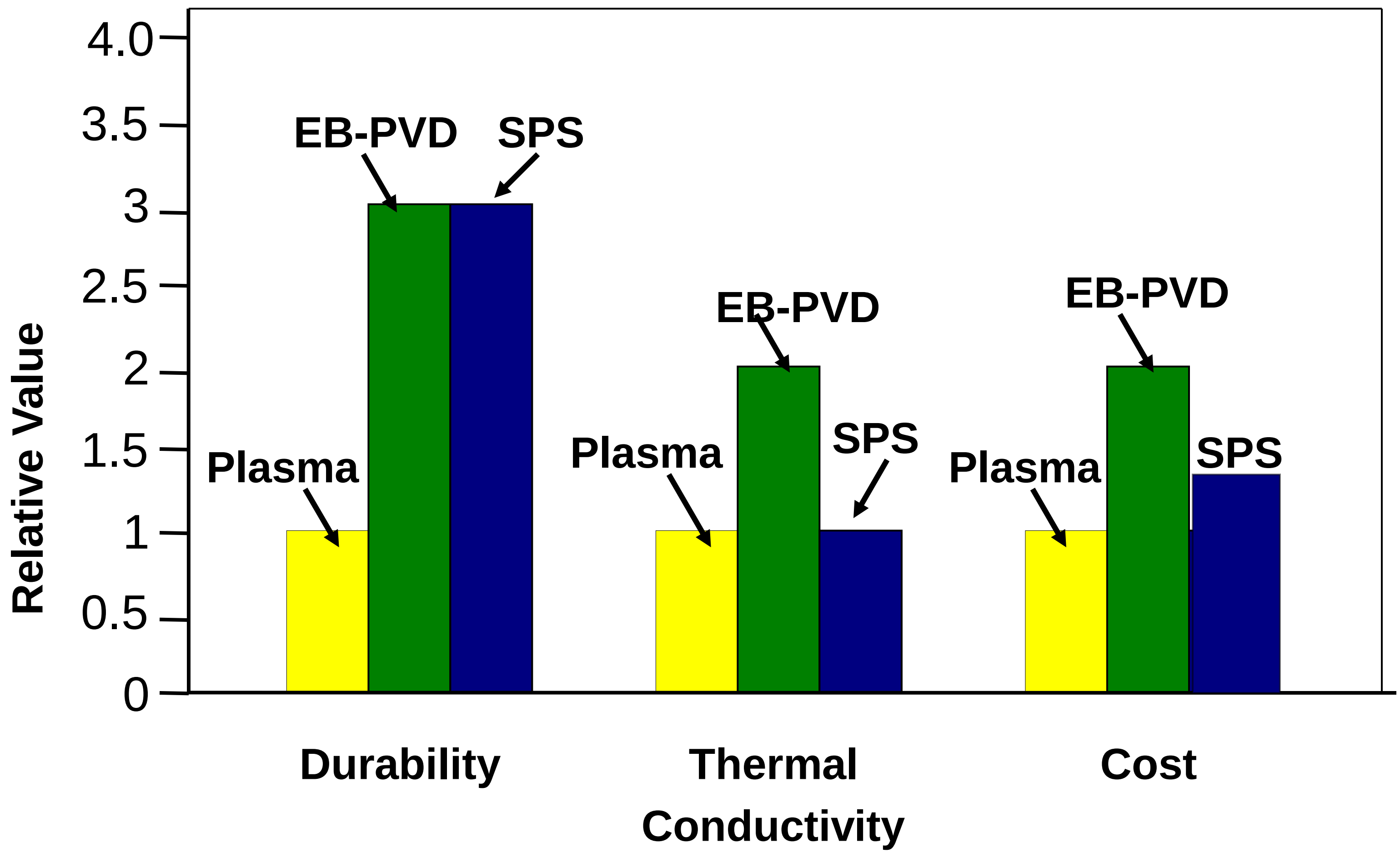


Delivery System v2.0

Thermal Cyclic Life Comparison for Different Types Of TBCs
(Nominal Thickness TBCs 12 mils)

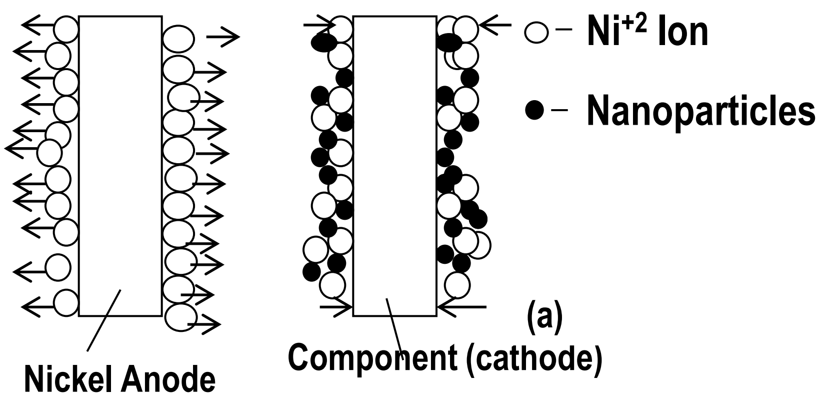


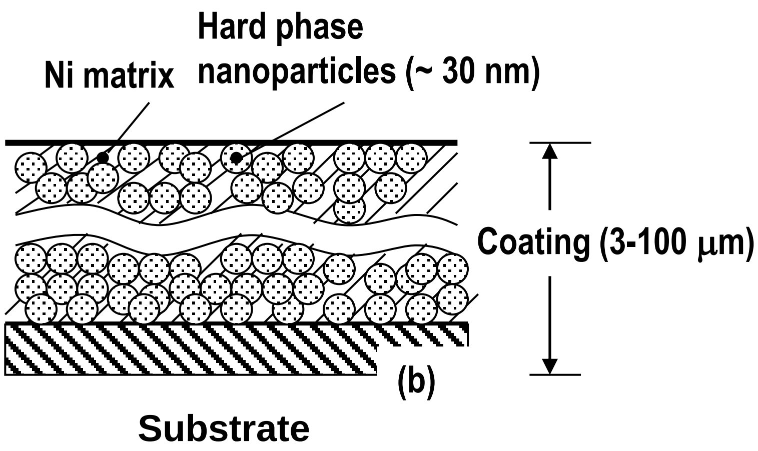
SPS Performance and Cost Analysis

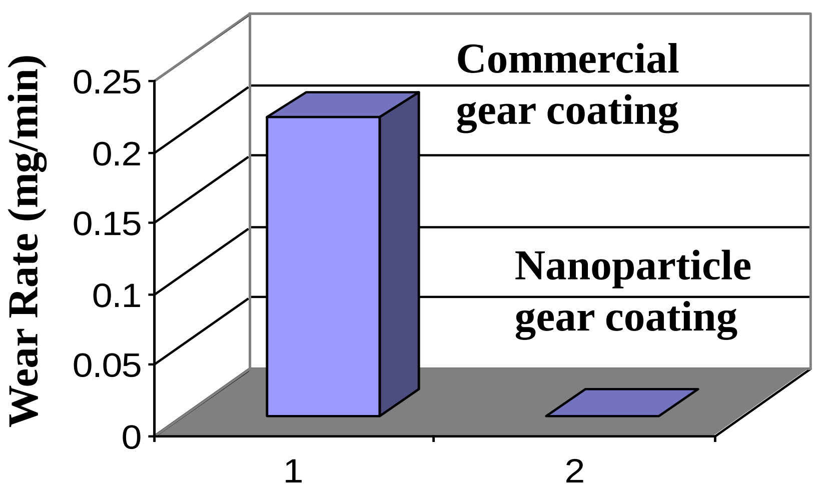


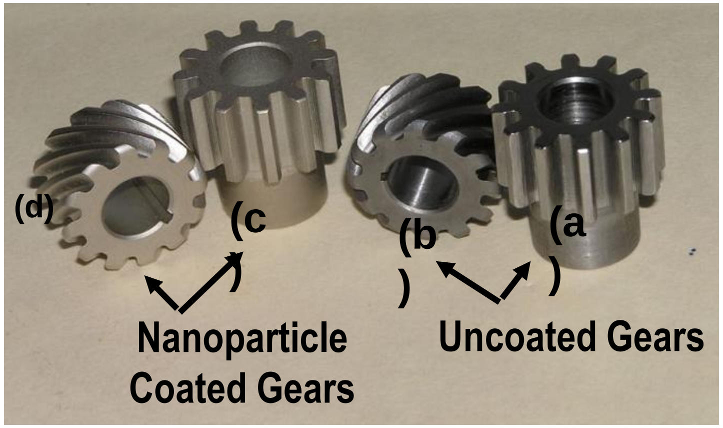
Electrodeposition Nanocoatings

Electroplated Nanocoatings for Transmission Gear Surfaces







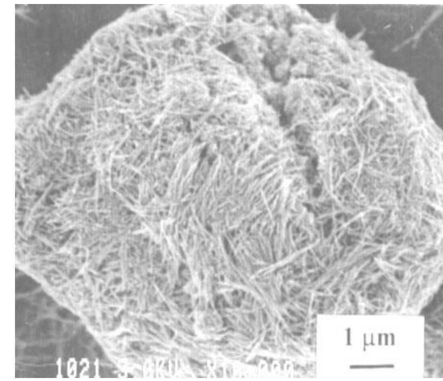


inframat®

Solid Lubricant Coatings for Race Car Transmission Gears

- ***Navy contract $850,000***
- ***Indy Car gearbox application***
- ***Dreyer & Reinbold Racing (Carmel, IN)***
- ***Current range is 800-1500 miles (may add another 1,000)***
- ***Opportunity to access***
  Newman-Haas Racing (Chicago), Hewland Transmission

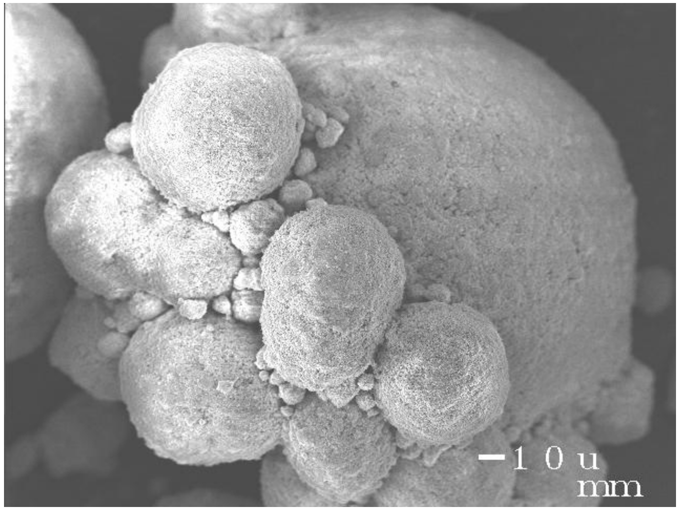
- ***Inframat*** *– Developed nano-composite to capture As/Pb - spray dried powders Owner of the patents*

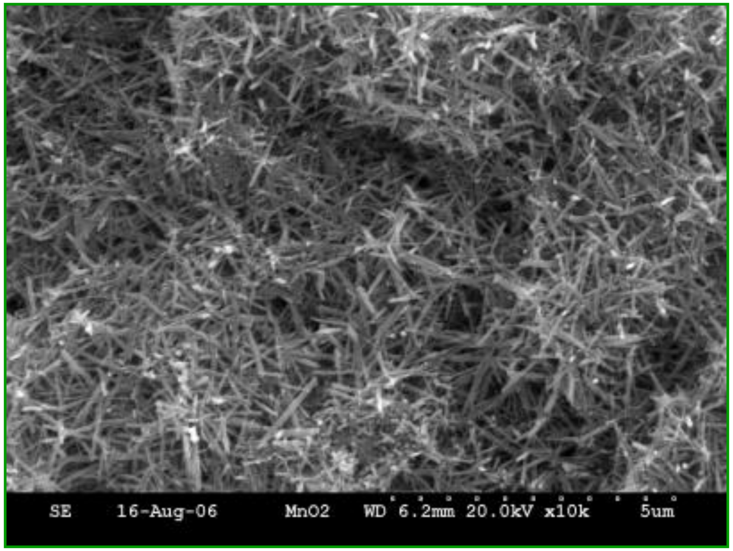


- ***MetaMateria*** *– Developed porous ceramic that holds desirable nano-materials*
  - *Made as granules or in monolith shapes*
  - *High interconnected porosity to allow hydraulic flow*

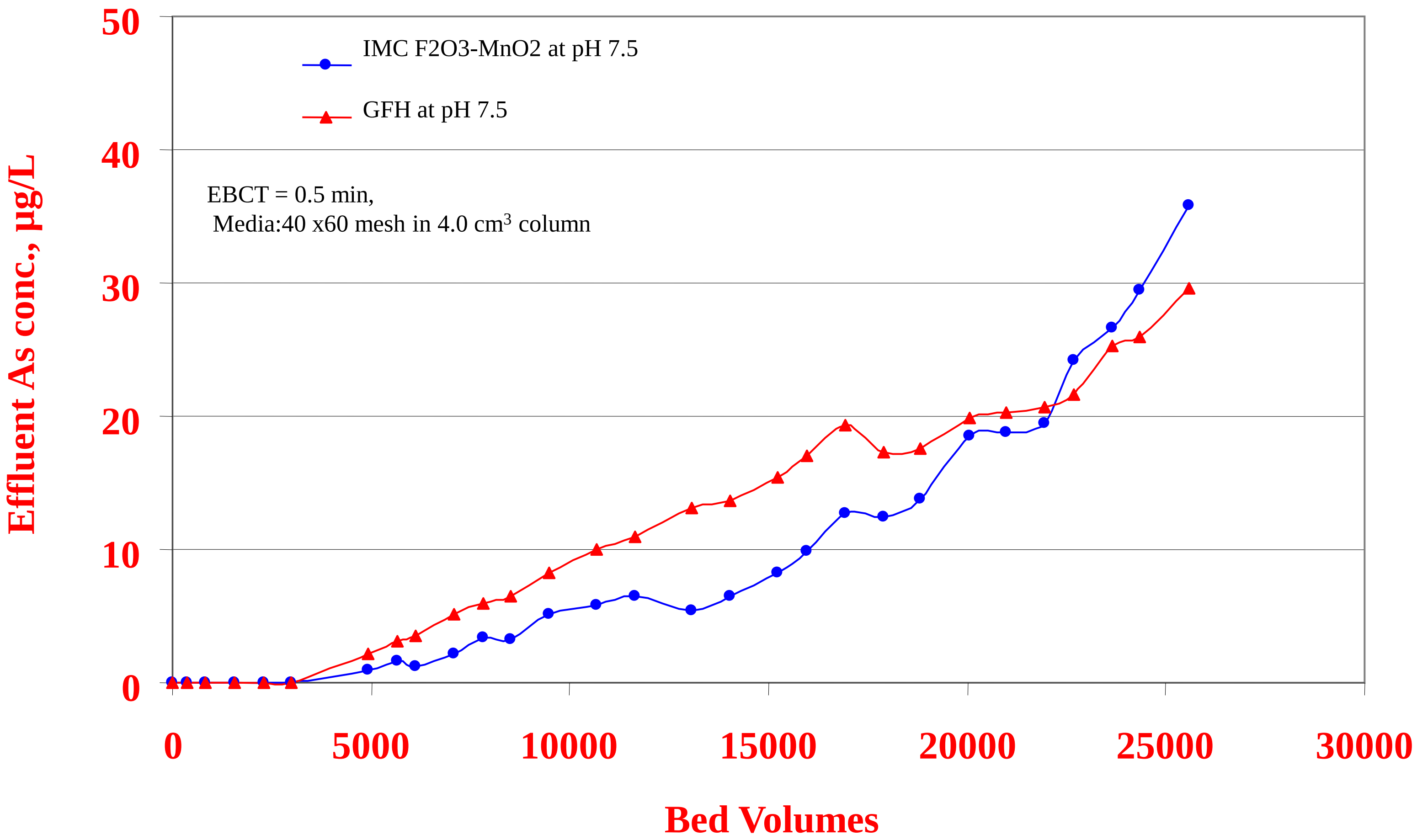
Inframat® High Surface Area Nano Media for sorption of Arsenic & Lead

- Use MnO_2 to oxidize As (III) to As(V)
- Use Nano-iron (FeOOH) to capture As(V)





Breakthrough
versus GFH Iron Precipitate



Nano lasts 50% Longer

inframat®

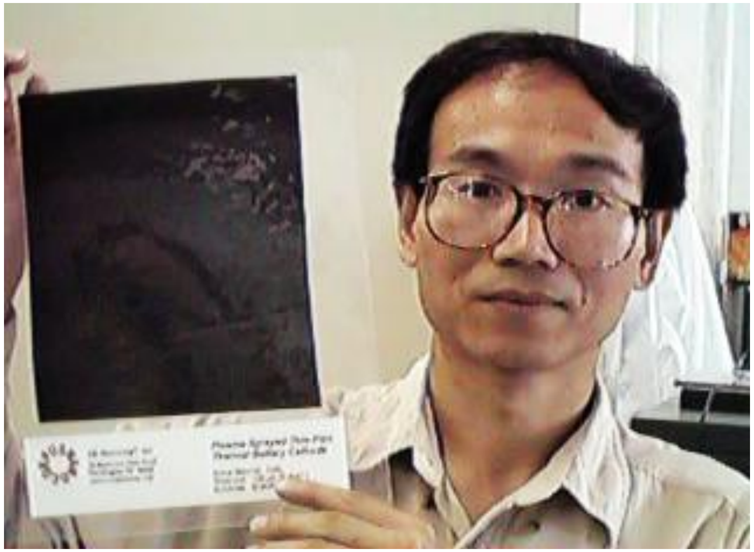
METAMATERIA

Inframat® ("IMC") - MetaMateria Technologies ("MMT") Joint Development for Commercial Media

- *Based on low cost Iron Foam made commercially by MMT*
- *Ideal platform to hold active materials*
- *Matrix is a highly porous ceramic (15 m^2/g)*
- *Nano oxide crystals of manganese/iron (MnO_2/Fe_2O_3) grown on surface (>70 m^2/g)*
- *High capacity for removal of As^{+5} and As^{+3}*
- *Anticipate ~ \$2-4 / lb in volume production*
- *Anticipate ~ \$60-125 / ft^3 in volume production assuming ρ_{disk} = 0.5 g / cm^3 (31.2 lb / ft^3)*

Don’t try this at Home!

Plasma sprayed FeS_2 cathode



Demonstration of flexibility

inframat®

Nanomaterials Commercialization Issues

- ***Materials Technology Development Slow***
- ***End-User Validation-Verification Process Slow***
- ***Beware the Dreaded "C" Word – Commoditization***

but…

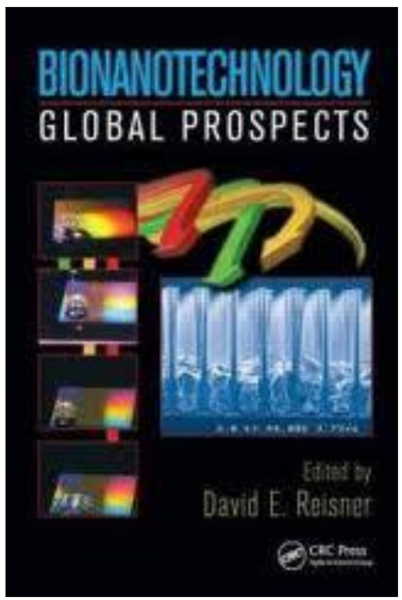
- ***Products become <u>Embedded</u>* and <u>Critical</u>****
- ***Products can have Very Long Lifetime***

***James Moore, <u>The Death of Competition</u>**

Shameless plug !

Bionanotechnology: Global Prospects
Bionanotechnology: Global Prospects II
Aquananotechnology: Global Prospects

David E. Reisner, Editor



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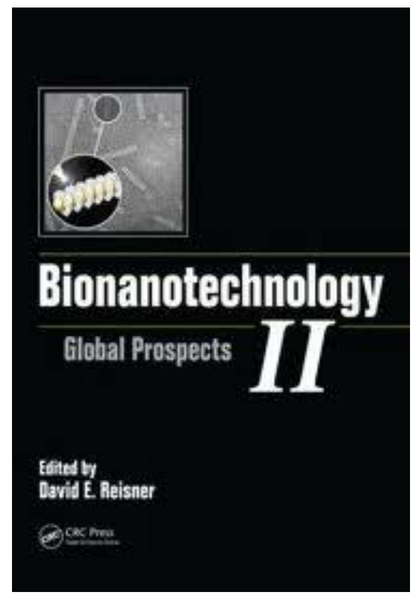

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