NanoRidge

Corporate Overview

Contains NanoRidge Materials proprietary information

NanoRidge Overview

- Incorporated in 2004
- Licensed university technologies portfolio
- 12 full time employees
- Develop nano-enhanced materials for specific customer needs
- Manufacture chemically modified nanomaterials

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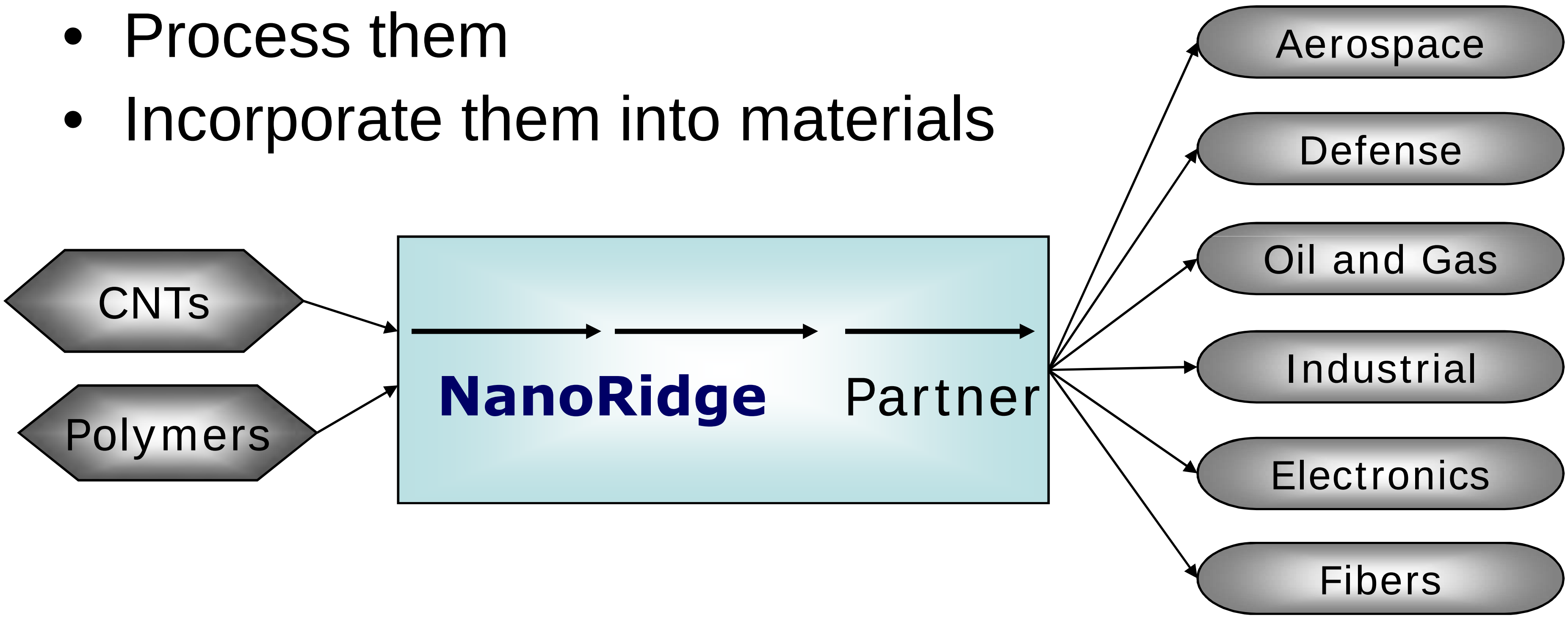
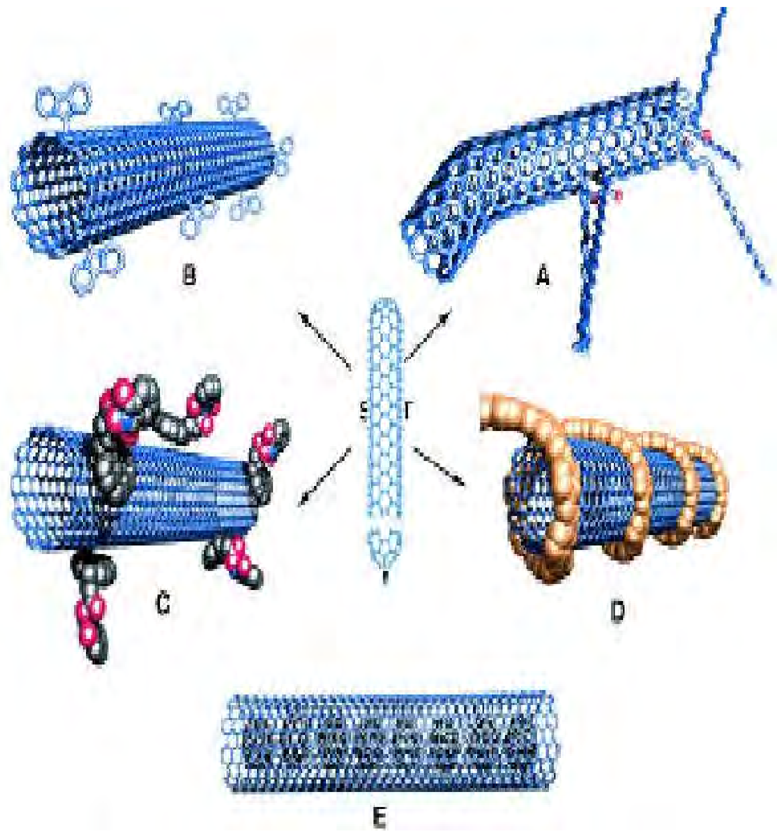
Where NanoRidge Fits In

- Purchase nanomaterials
- Process them
- Incorporate them into materials



Chemical Functionalization of Nanotubes

- Regarded as the key to efficiently exploiting nanotubes for mechanical reinforcement
    - •Natural bundles must be dispersed
- Choice of functional group critical
    - •Chemistry of carbon is extremely versatile
    - •Functional group has major effect on resin property enhancement
- NanoRidge has strong foundational IP and industry-leading expertise in nanotube functionalization and incorporation into composites



Picture Source: Andreas Hirsch, 2002

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NanoRidge Technologies are the Key

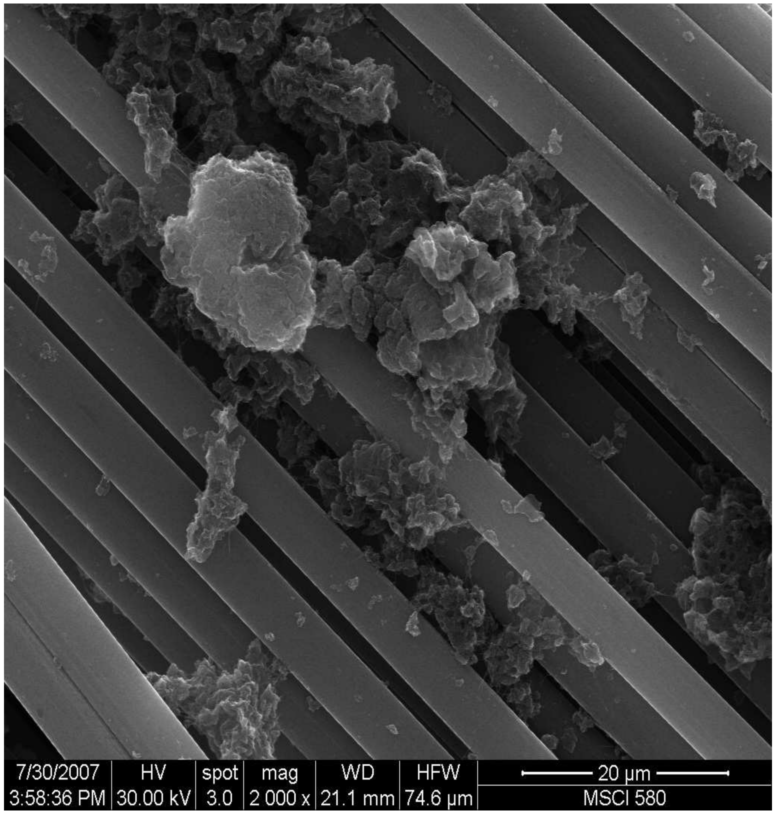

Figure A: As-received nanotube agglomerates “dispersed” on surface of fibers

NanoRidge Processing Technology

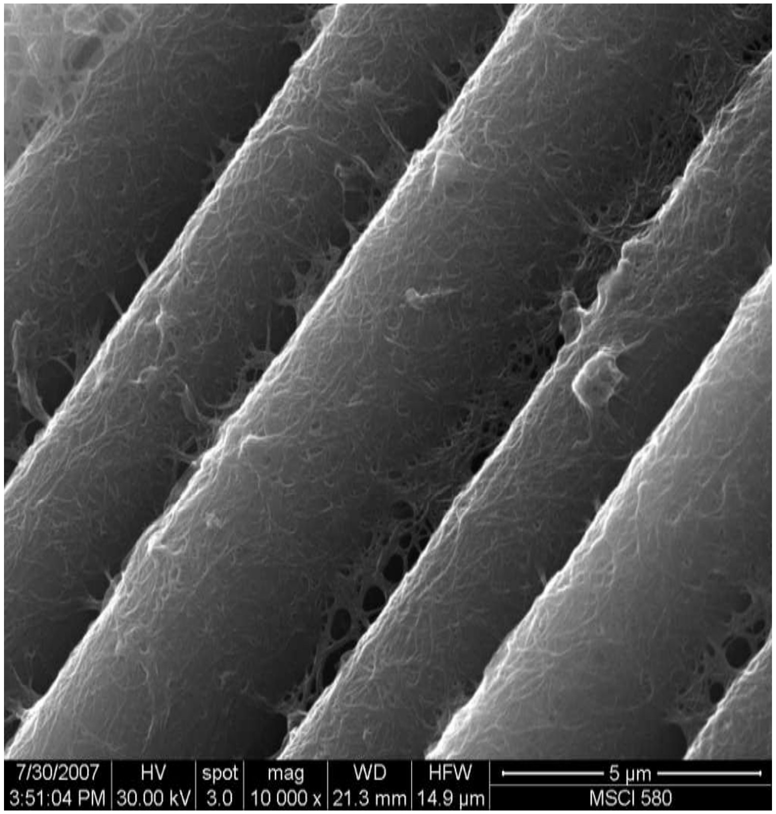

Figure B: NanoRidge functionalization and processing technologies result in uniform nanotube dispersion on fiber surface

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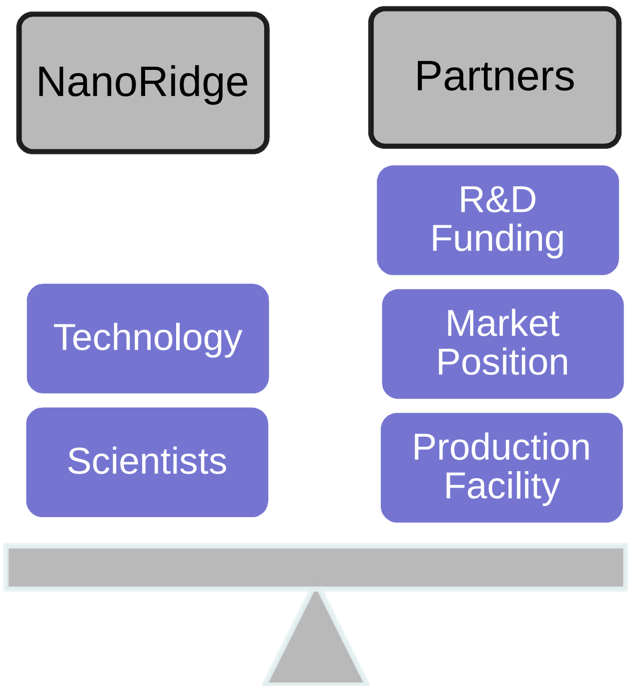
Key Technologies Owned

- Functionalization methods and products
- Polymers incorporating nanotubes
- Structural composites incorporating matrices with nanostructures
- Fibers with nanotubes in a composite structure
- Ceramics and metals incorporating nanotubes

Corporate Strategy

Technology Leverage



Commercialization Pathway

Research & Development

Initial internal assessment

Factors involved:

Scalability

Return on investment

Economies of Scale

Joint Development

Partnership designed to develop product for given application

Often funded by partner

NanoRidge determines appropriate treatment for nano material

Project concluded with product tests

Joint Venture or Sublicense

Partnership formed to spell out the terms for product manufacturing

Joint Venture Agreement will determine % of ownership and contribution

Likewise, a sub licensee will have associated royalties, etc.

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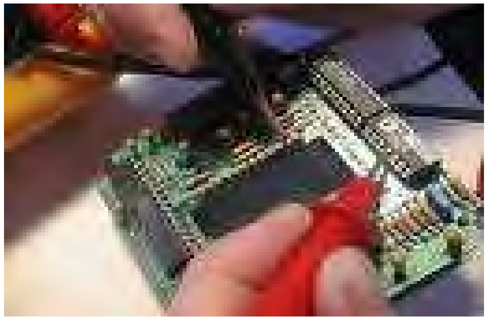
Commercial Projects

- Aerospace / Tier 1 suppliers
  - Structural composites
  - Aircraft interior
- Armament
- Oilfield services
- Engineering resin (in-reactor modification)
- Industrial gaskets and pumps (elastomer)
- Electrically conductive plastic (aerospace, electronics)
- Hardened metal alloys



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Elastomers for Oil & Gas Applications

- Nanotubes act as “rebar” for rubber
  - Provides property improvements not achievable by formulation changes
- Functionalization chemistry and nanotube incorporation methods developed for several elastomer types
- Major potential customers identified
  - Positive response to physical property data
- Joint Venture with Zeon Chemical (2008)
  - Back-integrate functionalized nanotubes into industrial process in current pilot plant facilities
  - Customer application qualification in-process

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Structural Composites Improvements

- Tensile strength +20%
- Fatigue life >10X
- Impact resistance +300%
- Thermal conductivity +2X
- Higher operating temperatures



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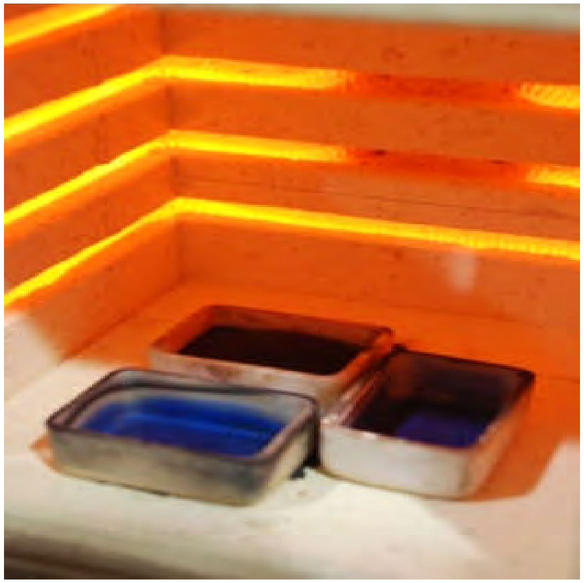
Nanotube Metal Alloys

- Functionalize CNT's for compatibility with various industrial alloys
- Targeted physical property effects
  - Tensile strength
  - Young's modulus
  - Hardness (grain size modification)
  - Wear rate & coefficient of friction
  - Fracture toughness (crack arrest)



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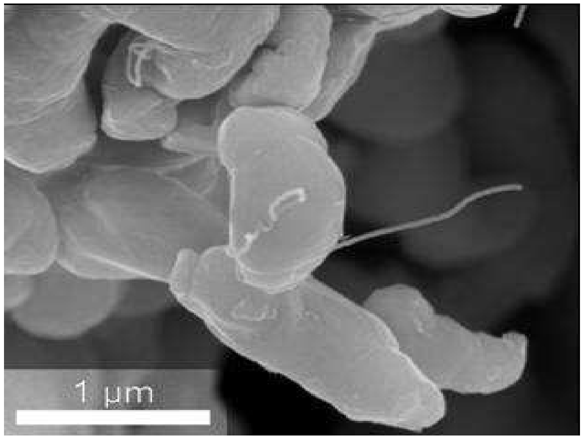
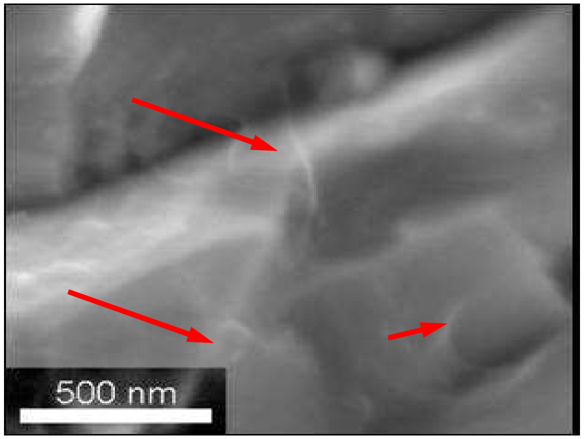
Enhanced Alloys – Current Projects

- Matrix strengthening of tungsten-carbide alloys
  - Joint development with major oilfield services company
  - Goal is to increase wear life of drilling tools
  - NMI provides CNT-enhanced alloy compositions
  - M-CNT survivability proven; preliminary mechanical test results by end of 2009
- Hardening of SS alloys for surface durability
  - Goal is to increase wear life of alloy-clad steel parts
  - Test plan under review for sample fabrication
  - Functionalized CNT's developed for high-Ni alloys



CNTs dispersed on matrix powder



CNTs survive after sintering

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Air Force STTR

- Air Force sponsored research to enhance PAN-based carbon fiber with carbon nanotubes
  - **Collaborator:** New Jersey Institute of Technology
- Phase I investigated monofilaments as proof of concept
- Phase I results
  - Demonstrated improved mechanical properties

Sample	Load at Break (gf)	Tensile strain at Break (%)	Modulus (gf/den)	Tenacity at Break (gf/den)
Blank PAN	255	7	118.05	3.69
SWNT / PAN	462	10	143.15	6.17
% Improvement	81%	43%	21%	67%

NJIT MDCL Medical Device Concept Laboratory

RICE UNIVERSITY

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Air Force STTR

- **Phase II Objectives:** Expand on Phase 1 successes → manufacture and test CNT-enhanced carbon fiber tows
- **Collaborator:** New Jersey Institute of Technology
- **Funding:** AFOSR, $750,000 for 2 years
  - Phase II awarded October 2009
  - Phase II commencement January 2010

NanoCable

<u>A NanoRidge/Boeing Joint Development Project</u>
<u>Co-Funded by NIST-ATP</u>

- Three year project to develop a lightweight electrically conductive polymer wire
- Utilize electrically conductive nanotubes embedded in a polymer matrix
- Markets: Aircraft, Satellites, Offshore Oil Production, Power Transmission, Electronics
- ATP award of $2.8MM, total project cost = $5.8MM

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Polymer Nano-Umbilical

- $560,000 funding for 1 year research project funded 80% by RPSEA/DOE
  - Similar technology as NanoCable
- Carbon nanotube polymer based conductor for extended seafloor tieback power delivery
- Technip, Duco, Chevron, Rice University collaborators

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NMI Thermoplastics with CNT's

- Resistivity ≤ 10^5 Ω·cm achieved at ≤ 5 wt. % CNT in:
  - PEEK
  - PEKK
  - HDPE, MDPE
  - Polystyrene (PS)
  - Polyphenylene sulfide (PPS)
  - Polyurethane, polyurethane-methacrylate
- Resistivity of 10^0-10^1 Ω·cm achieved at ≤ 10 wt. % CNT in:
  - PEEK
  - HDPE, MDPE
  - Polyurethane-methacrylate
- Higher CNT loading reaches 10^{-1} Ω·cm in PEEK, HDPE

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Electrically Active Polymers

NanoRidge is currently seeking application targets within several conductivity ranges

- ESD (10^5 – 10^{12} Ω·cm)
  - Electronic components (e.g. anti-static housings)
  - Anti-static automotive parts
- EMI (10^0 – 10^4 Ω·cm)
  - This area is our primary focus
    - NanoCable is an enabling technology in this space
  - “Heatable” spray-on coating system
  - Advanced electronic components (e.g. wire and cable shielding)
  - Non-metallic protection (e.g. polymer Faraday cage)
  - Other areas of mutual interest
- Lightning strike protection (~10^{-3} Ω·cm)

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Heatable Spray-on Coating System

- Base system is an “engineered” coating
  - Currently used for marine and anti-graffiti applications
- Characteristics include:
  - Moisture resistance
  - UV resistance
  - Acid/base resistance
  - Low permeability
  - Low surface energy
  - High durability
  - High flexibility
- Addition of nanotubes provides:
  - Resistive heating capability
  - Increased durability
- Primary applications include de-icing of airplane wing leading edges, wind turbine blades, and power towers
- Additional applications include oil & gas downhole applications

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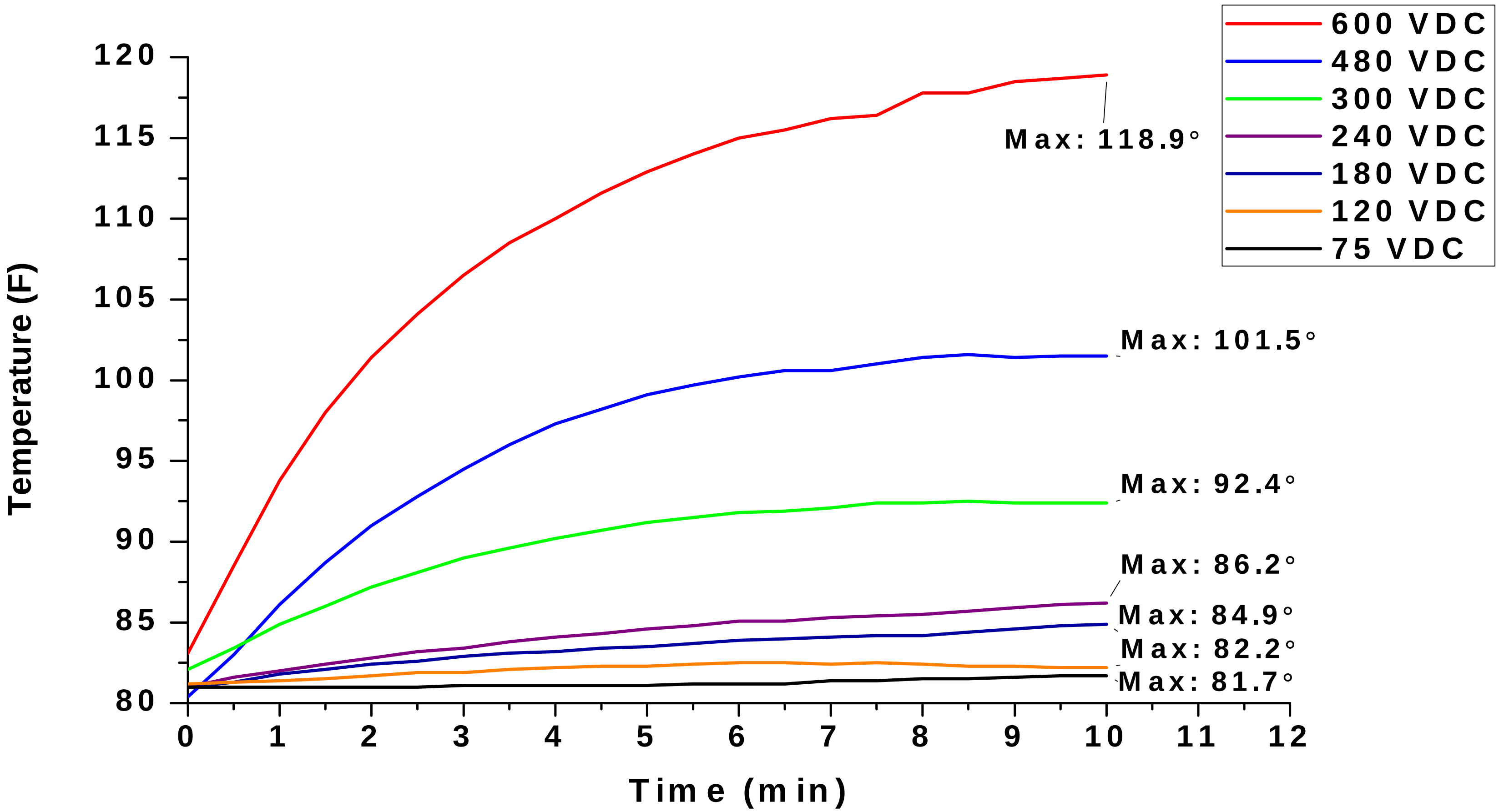
Heating Performance of Coating System



Time vs. temperature curves of heatable coating at various applied DC voltages

Heating Performance of Coating System

T= 0 min

T= 10 min

Business Development

- Growth through partnering
  - Conductive coatings
  - Electrically active thermoplastics
  - Metals
- Key partner parameters sought
  - Current market leadership
  - Innovative approach to corporate business development strategies
  - Funding for product initiatives
  - Longer term outlook for optimal value creation, but shorter term application potential

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