Bridging Nanoscience and Manufacturing

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Bridging Nanoscience and Manufacturing

• **Penetration of nanotechnology to practical systems/processes**
  - Practical applications demand large scale processes
    • Numerous engineering systems and processes (e.g. manufacturing) operate in harsh environments

• **Scale up nanomanufacturing**
  - Economical production of nano-building blocks
  - Control size distribution
  - Dispersion and stabilization of nano-building blocks
  - Large scale and controlled processing

• **Manufacturing engineers not well prepared**
  - Unprecedented knowledge challenges for manufacturing engineers educated under traditional curriculum
    • Understanding and use of quantum phenomenon and intermolecular forces becomes essential
  - Manufacturing physicist/chemists needed?
Metallic Nanomaterials

• Important for widespread applications
  – Structural applications
  – Functional applications
    • Electrical, magnetic, catalysis…
    • Thermoelectric, energy generation, propulsion…
    • Semiconductor, solar…

• Lightweight metallic nanomaterials (e.g. Al, Mg, Ti, TiAl)
  – Enhanced properties for lightweight materials
    • Significantly improve energy efficiency (e.g. for automotive and aerospace industries)
    • Reduce use of nonrenewable fuels and lower greenhouse gas emissions
  – Metallic nanocomposites for high temperature stabilities
Solidification NanoProcessing

From Nanoscience to Nanoproduction of Metallic Nanocomposites (Mg, Al, Ti, TiAl etc..)

Nanoparticles and Molten Metal
1. Incorporation
2. Mixing
3. Dispersion
4. ........

Solidification Nanoprocessing and Nanomanufacturing

Nanoparticles Fabrication and Production

Solidification of Metal Nanofluid
1. Particle pushing
2. Particle capture
3. Nucleation
4. Grain Modification
5. ........

Thermomechanical Processing
1. Heat treatment
2. Extrusion/rolling
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Thermal Drawing of Fibers with Individually Addressable Nanoelectrode Arrays

Existing and emerging applications
- cellular electrophysiology and cell-based assays, a global commercial market of several tens of billion dollars
- bioengineering, biomedicine, electrical engineering, materials science, and manufacturing science
Scientific and Technical Barriers

• Little success for a reliable and scalable nanomanufacturing (SNM) of fibers with continuous metallic nanowires (e.g. gold)
• There exists a fundamental size limit to the diameter of thermally drawn metal wires below which the metal.
• Fundamental constraints that pose severe challenges for scale-up manufacturing
  – Fluid instability induced by a low viscosity of molten metals
  – Large interfacial energy with the amorphous cladding materials
Research Approach

- A novel nanocomposite approach to tackle the grand challenges
- Highly interrelated activities to enable a reliable SNM of fibers with individually addressable nanoelectrode arrays (FIANAs)
  - Theoretical material and functional design
  - SNM of fibers with metal nanowires through thermal drawing
  - in-situ and ex-situ characterization
  - Develop cell-based assays
Laser Micro/Nano Processing and Manufacturing of Nanocomposites

Meso Die Surfaces

Meso nickel tool made using electro deposition in a master mold

EDMed Tool Insert

Micro tool insert made using EDM

Polished products

5mm wide “W” polished at 1mm²/s on ground Ti6Al4V surface

Rough micro/meso scale parts/devices

Pulsed Laser Micro Processing
Structurally Integrated Micro/Nano-Systems (SIMNS)

• Design, fabrication, and embedding of micro/nano sensors for multi-scale manufacturing
• Additive Manufacturing of “smart” tooling/components
  – *Solid Freeform Fabrication or digital manufacturing*
  – Direct print thin film electronics and sensors…
• Micro/Nano sensors array for power and energy systems
• Scaffold-Integrated micro/nano sensors and actuators for micro/nano-mechanobiology
Challenges in Harsh Environments

- Surface behavior dominance problematic in real world, especially in harsh environments
  - High temperature, high stress/pressure, electromagnetic interference, nuclear radiation, chemical, wear, corrosion (including biocorrosion) etc
- Existing knowledge base on narrow material bases
- Lack of basic understanding on behavior of micro/nano devices/components under harsh conditions
Micro/Nano Sensors for Engineering

- Continuous monitoring and control of thermal, mechanical, and biological responses in engineering systems
  - at or near interaction interface with unprecedented resolutions
  - Improved understanding of scientific fundamentals
    - Manufacturing, power/energy generation, oil exploration, biomedical…
  - Better product quality, higher productivity, lower cost