Processing of Nanocomposites

Frederick M. Gallant, Swami Gowrisankaran - Ph.D.. Students
Dr. Hugh A. Bruck – Asst. Prof., Dr. David I. Bigio – Assoc. Prof.
Constance Murphy, Dr. Suzanne Prickett – IH-NSWC

CECD
CENTER FOR ENERGETIC CONCEPTS DEVELOPMENT

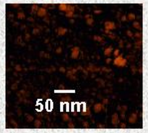
UNIVERSITY OF MARYLAND 18 56

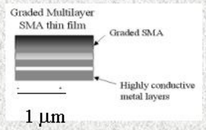
NAVSEA INDIAN HEAD Surface Warfare Center Division

WHAT IS A NANOCOMPOSITE?

- Materials featuring:
  1. Nanoparticle, nanofiber, or nanotube reinforcement in a matrix material
  2. Nanometer thick layers of different material systems or properties

Aluminum nanoparticles in epoxy





Graded Multilayer Thin Film

MOTIVATION AND NEEDS FOR NANOCOMPOSITES

MOTIVATION

Develop nanocomposites with controlled microstructures using twin-screw extrusion (TSE) processing technology and characterize their mmicrostructure and echanical behavior using microscopy techniques with Digital Image Correlation for developing models of their physical behavior

NEEDS

- **Processing Models for Predicting Effects of TSE Operating Conditions on the Microstructural Evolution**
- **Multiscale Characterization of Mechanical Behavior**
- **Property and Performance Models**

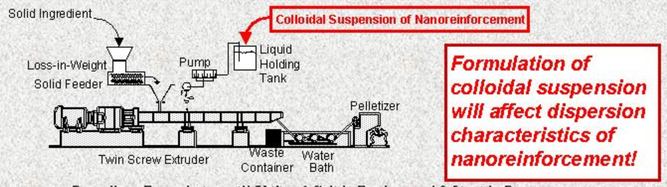
ADVANTAGES OF TSE PROCESSED NANOCOMPOSITES

- *Biologically Inspired Hierarchical Composites with Enhanced Mechanical Strength and Toughness*
- *Increased Dispersion of Aluminum Nanoparticles in Propellants for Improved Burn Rate Performance*
- *Functionally Graded Materials with Optimized System Performance*
- *Oriented CNT Composites with Novel Anisotropic Physical Properties*

RESEARCH APPROACH

- ***Processing***
  1. Preprocessing of nanoparticles in colloidal suspensions to minimize agglomeration
  2. Addition of nanoparticles at different locations in extruder
  3. Design of extrusion head to control orientation of nanofibers and nanotubes
- ***Characterization***
  1. Advanced microstructural characterization techniques such as Atomic Force Microscopy (AFM)
  2. Multiscale mechanical characterization techniques such as Digital Image Correlation and Hardness Testing

TSE PROCESSING OF NANOCOMPOSITES



Formulation of colloidal suspension will affect dispersion characteristics of nanoreinforcement!

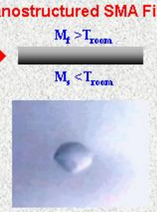
Propellant Formulation will Utilize 3 Solids Feeders and 2 Liquids Pumps

- **28 mm Lab-Scale Extruder — UMD/College Park**
- **40 mm Pilot-Scale Extruder — NSWC/IHDIV**

SPUTTER DEPOSITION OF NANOSTRUCTURED FILMS

ATC 1200 Sputtering Machine

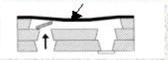
Nanostructured SMA Film



"Microbubble" forms when film is heated

Can vary stoichiometry and recrystallization kinetics of film through sputtering conditions to control nanostructure for novel performance!

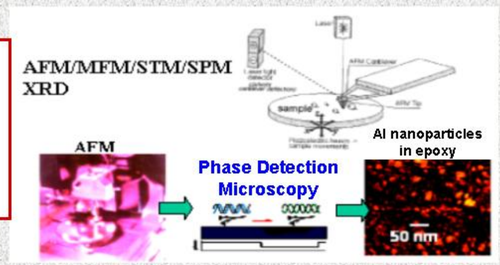
Nanostructured SMA Film



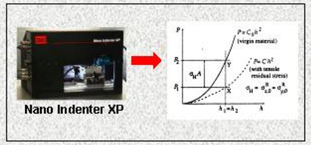
Micropump Concept

MICROSTRUCTURAL CHARACTERIZATION

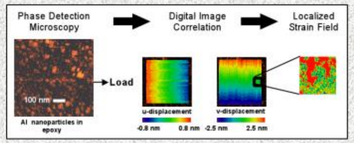
Can characterize microstructure using microscopy techniques, like Atomic Force Microscopy (AFM), with nanoscale resolution!



MECHANICAL CHARACTERIZATION



Property and Stress Characterization using Hardness Testing



Deformation Characterization using Digital Image Correlation

SUMMARY

1. TSE processing of nanocomposites with controlled microstructures (*hierachical, dispersed, graded, oriented*)
2. New TSE processing models for nanocomposites based on convoluting RVDs with operating conditions for predicting microstructural evolution
3. Microstructural characterization using AFM techniques
4. Multiscale mechanical characterization using Hardness Testing and Digital Image Correlation