HV Propulsion Materials

Deformation in Ceramics

Project (PM 11196)

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Deformation in Ceramics

21CTP Technical Goal: Develop and demonstrate an emissions compliant engine system for Class 7-8 highway trucks that improves the engine system efficiency from ~42% today to 50% by 2010.

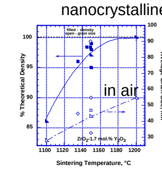
Project Objectives
•Develop processing technology for producing dense, nanocrystalline ceramics in bulk and coating forms.
•Optimize nanocrystalline ceramics for applications in both advanced sensor and wear-resistant applications.

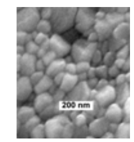
FY 2005 Focus
•Develop processing technology for thin bodies and coatings.
•Explore feasibility of more conventional powder processing methodologies for fabricating nanocrystalline ceramics.

Planned Duration
October 2003 to September 2007

DOE Funding/Industry Cost Share
FY04: $200K; FY05: $140K

Combination of novel pressure-less sintering and colloidal processing approaches yield dense, nanocrystalline zirconia ceramics





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Accomplishments
•Demonstrated feasibility of fabricating thin components of dense zirconia with < 60 nm grain sizes.
•Developed powder processing based on granulation technology, which is more robust and more amenable to commercial production.

Significant Future Milestones
Complete initial optimization of fabrication of dense nanocrystalline ceramics using granulation technology. (December 2005)

Project ID/Agreement ID	Program Structure	Sub-Program Element	R&D Phase	Date
PM_11196	Materials Technology	HV Propulsion Materials	Exploratory R&D	8-12-05

Objectives

- Optimize particulate synthesis and processing to fabricate high density powder compacts.
- Devise pressure-less sintering approaches to produce dense bulk nanocrystalline ceramics.
- Evaluate deformation forming utilizing plasticity in nanocrystalline ceramics and explore electric field effects to promote deformation.
- Address properties for applications including wear and structural components and electrochemical devices (e.g., engine sensors).

Relevance to 21CT Goals

- Develop advanced sensor and wear materials to increase engine efficiencies
- 21CT Partner involvement:

  Exploratory R&D

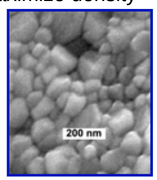
Technology Transfer

- Current collaborators
  - Prof. Hans Conrad North Carolina State University
- Potential commercialization pathway
  - MetaMateria

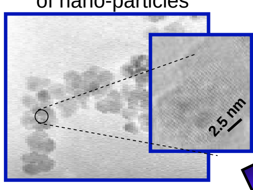
Approach

- Evaluate (1) colloidal processing combined with pressure casting and (2) granulation approaches to form high density "green" compacts.
- Optimize "transient" sintering to prepare bulk nanograin ceramics.
- Characterize thermo-mechanical properties.

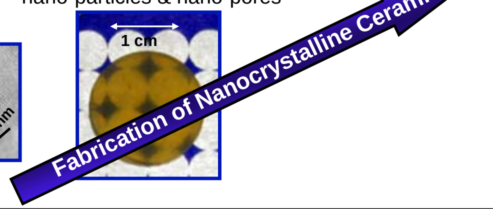
Densification approaches to minimize grain growth & maximize density



Synthesis and dispersion of nano-particles

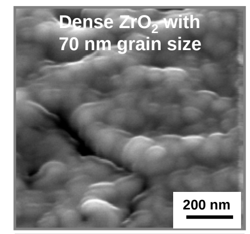


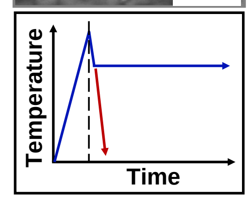
High particle packing nano-particles & nano-pores



Technical Accomplishments/ Progress/Results

- Produced uniform, high green density bodies using colloidal approaches.
- Modified "two-step" sintering" approach to achieve a shorter, energy efficient cycle.
- Demonstrated fabrication of dense bulk zirconia ceramics with 35 -100 nanometer grain sizes by via "transient" sintering.
- Developing granulation powder processing approach that is amenable mass production.



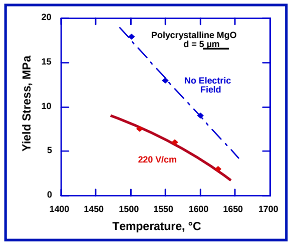


Technical Accomplishments/ Progress/Results

- Decreased grain size (< 60 nm) substantially reduces deformation temperature in ZrO_2.

Grain Size nm	Yield Stress MPa	Temperature Required °C
55	20	1100
400	15	1500

Applied electric field shown to promote plastic deformation in ceramics.



Future Work

- Continue to refine colloidal processes for bulk materials
- Optimize granulation-based fabrication technology.
- Optimize green body characteristics (e.g., porosity, packing density) to enhance densification of granulation-based materials.
- Evaluate wear and thermo-mechanical properties of dense, nanocrystalline bulk ceramics and coatings.
- Investigate “Sinter-Forging” process for forming dense materials with grain sizes << 50 nanometers.
- Collaborate with MetaMateria (high technology company) to explore commercial viability of fabrication routes.