Multi-component Nanoparticle Based Lubricant Additive to Improve Efficiency And Durability in Engines

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DOE VEHICLE TECHNOLOGIES PROGRAM ANNUAL MERIT REVIEW

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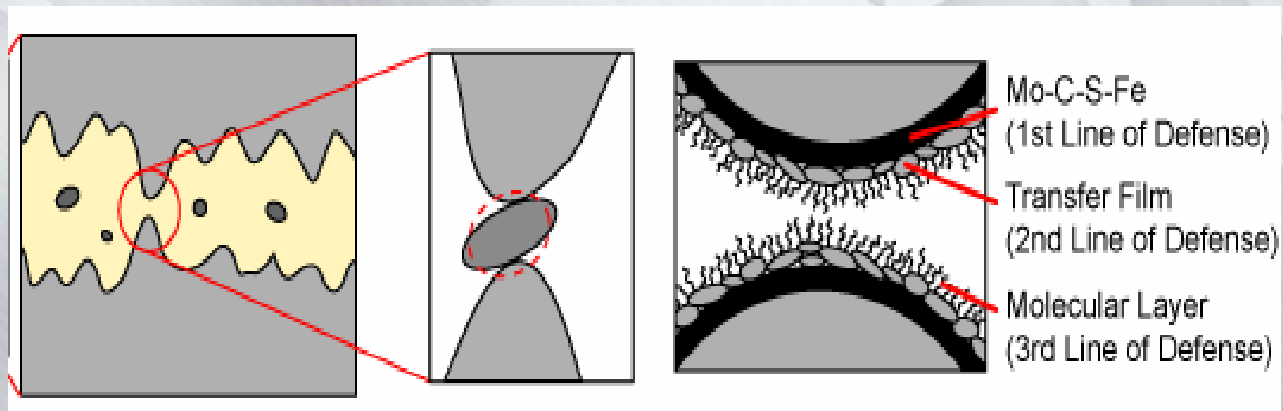
Outline

- Purpose of work
- Barriers
- Approach
- Performance Measures and Accomplishments
- Plans for Next Fiscal Year
- Summary



Purpose of Work

- Material selection criteria for improving boundary lubrication at the asperity contact zone
- Designing of active nano particulate lubricant. Size and pressure sensitive architecture capable of delivering stable transfer layer





Barriers

- Prevent progressive wear, lower friction and improve efficiency and durability in engines
- Additive system for lubricants that will minimize sulfur and phosphorus content and lower ash forming elements
- Advanced lubrication technology for cleaner emission



Approach

Phase 1

Nano Lubricant Development

Bench-top Friction & Wear Testing

Characterization
- Worn surface
- Composition & Chemistry

Phase 2

Component level Testing

- **Very close communication/consultation with team members**

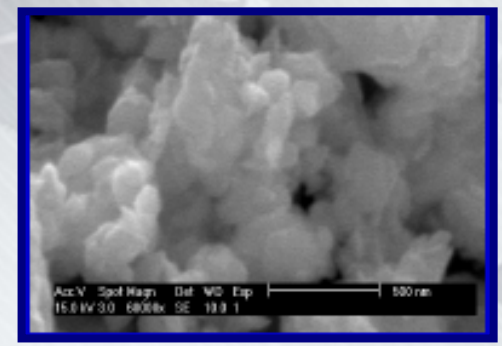


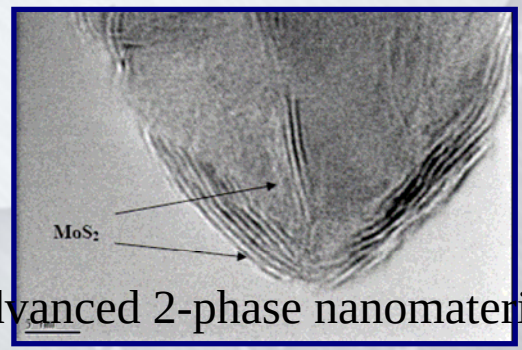
Approach

Top down particle architecture

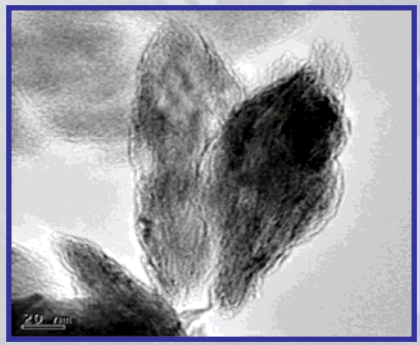
Multi-component

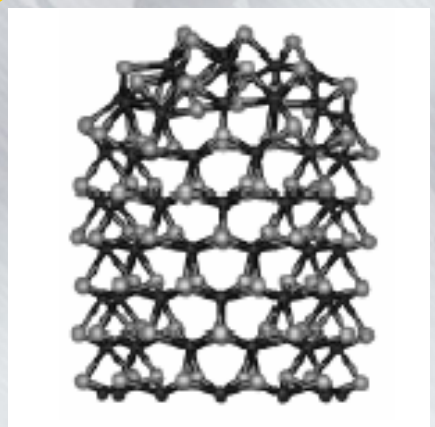
Surface stabilization and dispersion



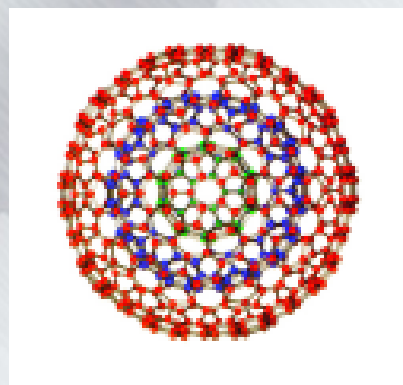


Advanced 2-phase nanomaterial





MS_2 nano tube



IF-MS_2 (fullerene structure)

Conventional nanomaterials

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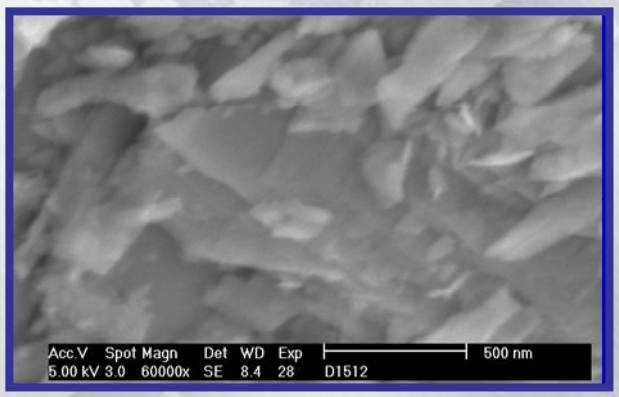
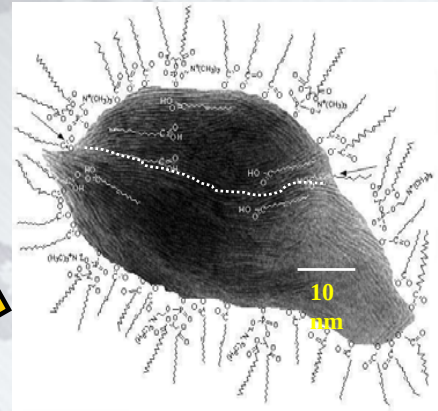
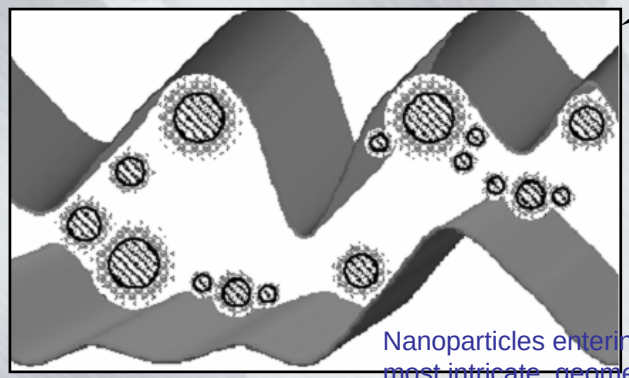
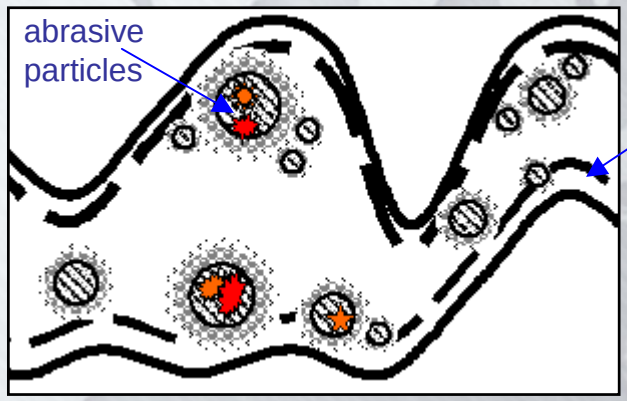
Lubrication Process







Nanoparticles entering most intricate geometries



Particles are not depleted in low load environment

At high load few nanoparticles will shear into intrinsic layers and few will trap abrasive wear particles

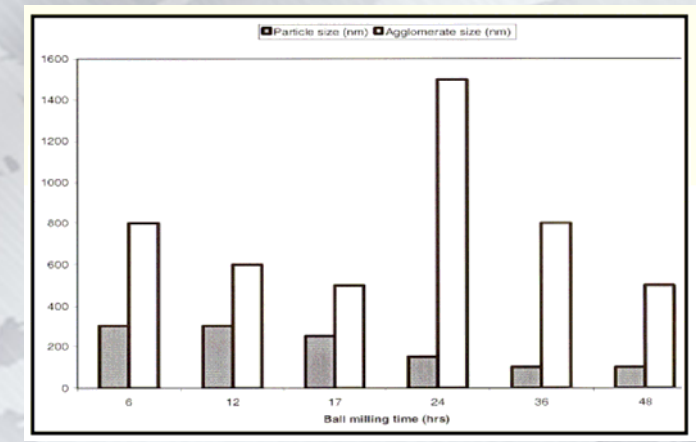
Technical Accomplishments (till date)

- Identify a manufacturing friendly process for nanoparticle development
- Develop a parametric window for particle generation with reasonable particle size distribution
- Transfer layer mechanism of nanoparticles in tribological system
- Physical / chemical understanding of particle stabilization

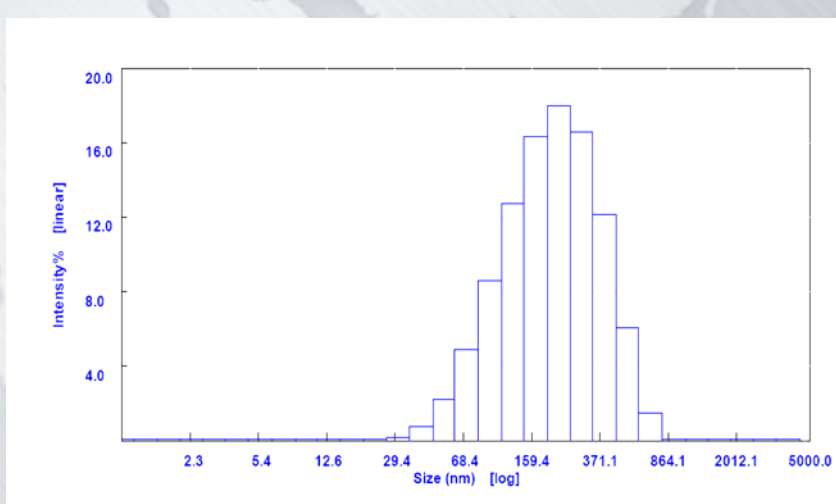


Particle Architecture

- ✓ Processing method
- ✓ Effect of environment
- ✓ Morphology and shape
- ✓ Surface energy
- ✓ Stabilization



Particle size w/time



Particle size distribution

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Particle Stability

Unstabilized nanoparticle in oil

Stabilized nanoparticle in oil

XPS analysis

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Technical Advantages

- Absence of dangling bond: makes them chemically inert (oxidn & thermal)
- Nanometric size: allows them to easily enter the contact area
- Weak inter-planner bonds: delamination under high contact stress

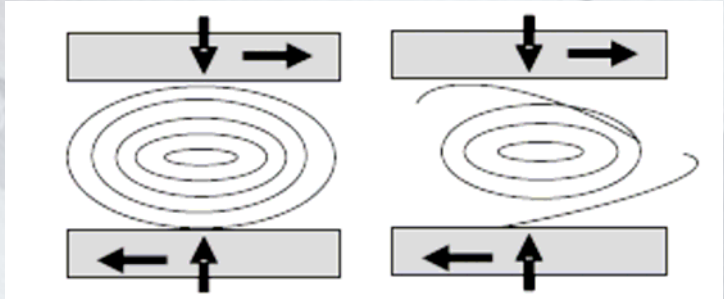


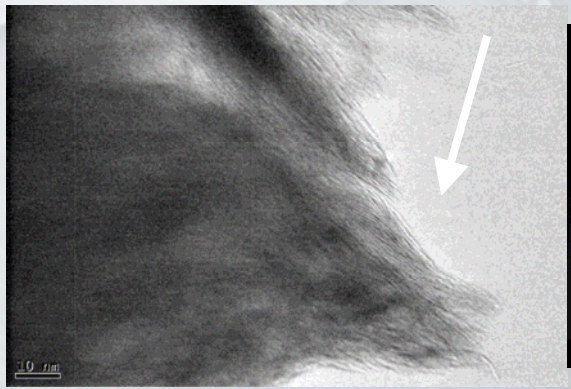
Lubrication Mechanism

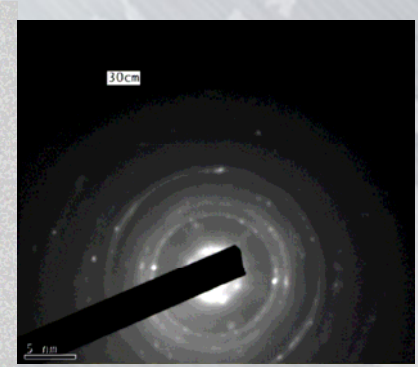
- Pressure sensitive architecture
- Exfoliation of external lamellar sheet
- Transfer of lamellar sheet (active component) to the contact zone

Hertzian contact

(pressure and shearing)

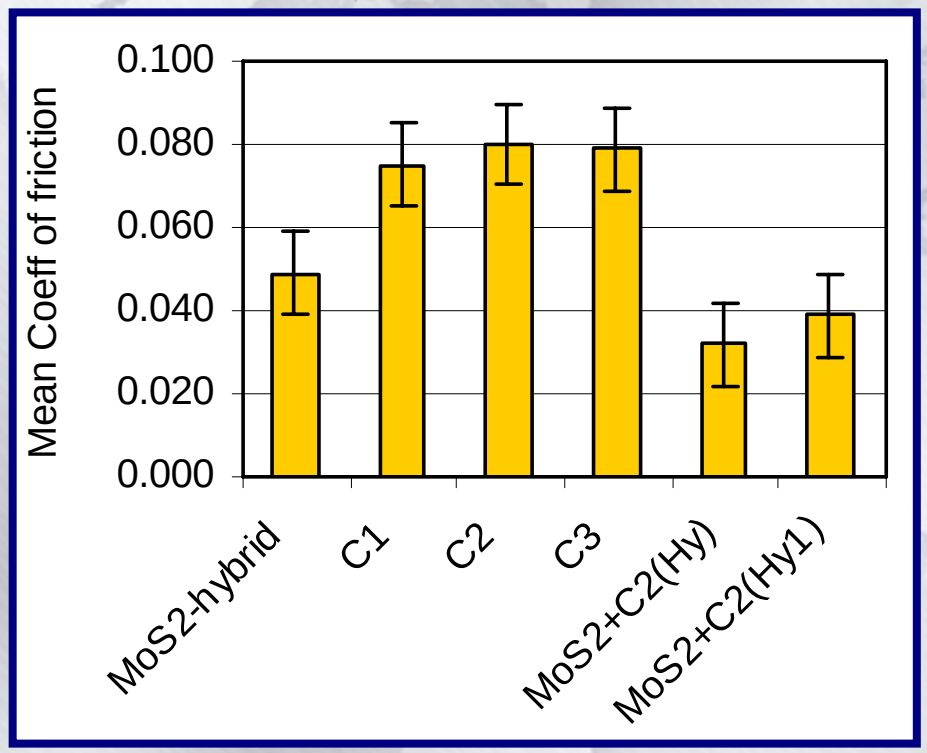


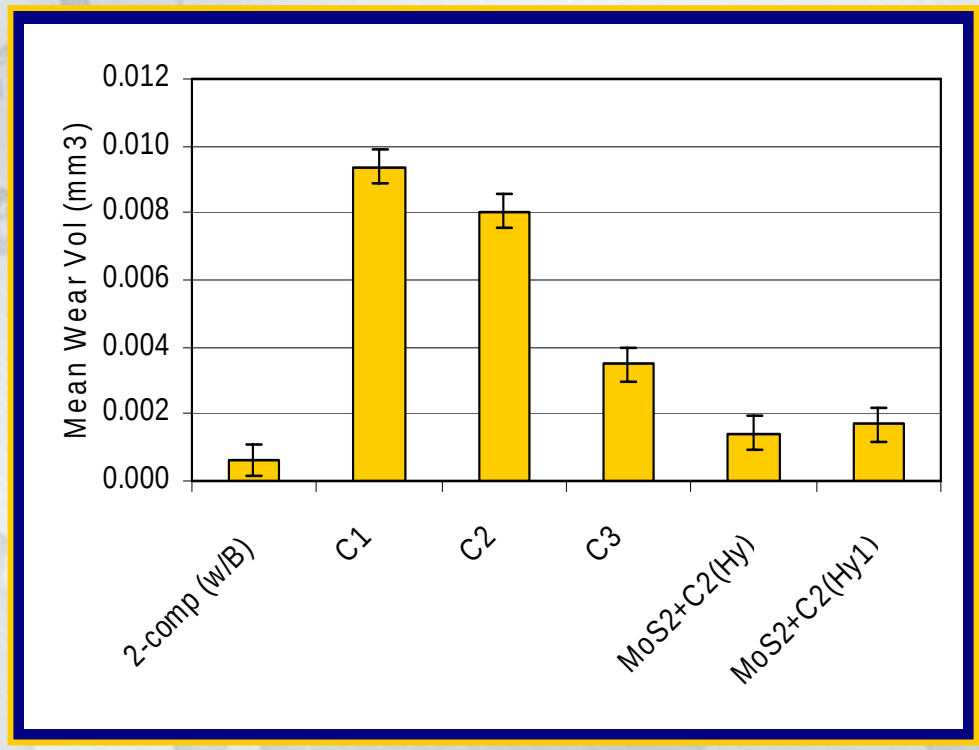




Tribology of nano-lubricants

BOR wear test; unidirectional





- **Nano materials highly effective in reducing friction & wear**

Accomplishments & Milestones

(till date)

Project milestones	Oct'07 - Dec'07	Jan'08 - Mar'08	Apr'08 - Jun'08	Jul'08 - Sep'08	Oct'08 - Dec'08	Jan'09 - Mar'09	Apr'09 - Jun'09	Jul'09 - Sep'09
Selection of application specific chemical components for active nanoparticle system	♣							
Design, develop and optimization of process parameters for active multi-component nanolubricant materials	♦ ♥	♠						

Project kickoff (October 1, 2007)

(Feb 2008)

- ♣ ***Primary particle identification***
- ♦ ***Process***
- ♥ ***Film transfer mechanism***
- ♠ ***Stabilization***



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Technology Transfer

- Technology to reduce friction and mechanical energy losses in engine: potentially improve efficiency
- Environmental benefits by reducing green house gases and other emissions due to decreased fuel consumption
- Offers a roadmap to more eco-friendly technology with potential for low SAPS
- Process scale-up, cost analysis and nano-manufacturing considerations for product realization (included in project task)



Future Work (milestone date)

- Continue material selection criteria for improving lubrication (Mar'08)
  - Organic-inorganic material selection
  - Right boundary film chemical selection
- Continue designing of active nanomaterials (Jul'08)
  - Enhance particle architecture
  - Optimize process conditions
  - Optimize particle stabilization and dispersion mechanism
- Systematic physical and chemical characterization (Jul'08)
- Lab testing to validate lubrication characteristics (Sep'08)
  - Design test method & post-test analysis



Summary

- Advanced lubrication for engine with potential to reduce friction and wear characteristics and low SAPS
- Novel nanomaterial based technology with active organic-inorganic particle architecture
- Identified a manufacture friendly process for nano-particle generation. Understand transfer layer mechanism and particle stabilization process
- Offers a nanomaterial technology for low friction / wear in engine with cost and scale-up analysis
- Continue material selection and optimize design process. Lab validation of lubrication characteristics of active nanomaterials