Advanced Nanoparticle Lubricant Additives
The Challenge

Friction and wear are significant sources of energy and material losses in mechanical processes and thus lubrication--which can mitigate these losses--is a principal focus of efforts to improve energy efficiency and mechanical durability.
# Broad Range of Segments

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<th>AUTOMOTIVE LUBRICANT ADDITIVES</th>
<th>GENERAL INDUSTRIAL LUBRICANT ADDITIVES</th>
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<td>Hydraulic fluid</td>
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<td>Heavy-duty motor oil</td>
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<td>Passenger car motor oil</td>
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<td>Tractor hydraulic fluid</td>
<td>Other general industrial oil</td>
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<td>Two-cycle engine oil</td>
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<th>INDUSTRIAL ENGINE OIL ADDITIVES</th>
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<td>Extreme-pressure/antiwear/antiseize additives</td>
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<td>Friction modifiers</td>
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<td>Pour-point depressants</td>
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<td>Viscosity index improvers</td>
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<td>Others</td>
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Diverse Lubrication Applications

Systems

Gears

Transmission

Bearings

Pumps

Camshaft

Sub-systems
Challenging & Multiple Requirements

- Material compatibility
- Low friction characteristics
- Additive compatibility
- Impact on AT devices
- Advanced Lubricant Requirements
- Thermal stability
- Contaminants and noise factors
- Environmental impact
- Heat transfer & cooling
- Acceptable viscometrics

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Introducing NanoGlide®!

- NanoGlide® is our lubricant additive technology platform
  - Designed through nano-engineered multi-functional formulations for highly loaded components
  - Addresses a global need to save energy and enhance durability of equipment.
Why is **NanoGlide** Different?

- Most lubricants are liquid oil-based materials
  - Fatty acids
  - Mineral and synthetic oils (groups I, II, III, IV, and V)
- Solid lubricants (inorganic layered materials)
  - Molybdenum disulfide (MoS$_2$),
  - Tungsten disulfide (WS$_2$),
  - $sp$-bonded carbon:
    - Graphite
    - Fullerenes/nanotubes
- NanoGlide combines inorganic and organic phases (hybrid form) at nano-scale as an additive
  - Pastes
  - Greases
  - Suspensions
  - Colloids
Fundamentals of Lubrication

- Liquid lubricants fail under:
  High load/pressure (1-2 GPa) &
  High local temp. (150-300 °C).
Overcomes These Challenges

Boundary Lubrication:
- Liquid lubricant oil is squeezed out
- Friction at asperities (tips)
- High temperature, high wear, and friction.

NanoGlide Inorganic-organic nano-engineered lubricants:
- Inorganic nanoparticles:
  - Doping with additional functional materials (for EP and/or HT applications),
  - Integrated with additional functional groups and/or N-containing).
- Organic capping layer:
  - High dispersion stability,
  - Protects from aggregation,
  - Additional functional groups (DDP).
How NanoGlide Works

Molybdenum disulfide raw material

Nanoparticles entering most intricate geometries

Particles are not depleted in low load environment

Reactive Milling

NanoGlide Particle

Shearing under high-load can trap abrasive detritus
The **NanoGlide** Technology Delivers:

- A unique active nano-particulate lubricant
- A size and pressure sensitive architecture capable of delivering a stable transfer layer
- Nano size: Allows easy entry to the friction contact area
- Laminar structure allows lubrication through delamination under high contact stress

**Advanced 2-phase Nanomaterial**
Example Test Comparatives
Friction and Wear
NanoGlide® Reduces Friction and Wear in a Range of Tests and Lubricants

Block on Ring wear test (500 rpm, 75 lbs., 30 min)

- Common additive
- Common additive + NanoGlide NG1D1I
  - Effective from the 1st cycle at ambient temperature

Gear scuffing test with NanoGlide NG1D2HL

Base stock
Load = 239.3 Nm
Scuffed

Base stock with NanoGlide
Load = 304 Nm
No scuffing

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Coefficient of Friction
4 Ball Test

- Micro-particles: Commercial
- Base Oil
- Nanoparticles: Unfunctional
- Nanoparticles: Hybrid in oil
- Base oil & additive
- Nanoparticles: Hybrid and Functional

Test Duration, Minutes

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Block on Ring Test Shows 50% Friction & Wear Reduction!
Pin-on-Disk Test Result Also Shows Lower Friction

- Sample A - Base oil
- Sample B - Base oil with organic agents
- Sample C - Base oil with hybrid inorganic NanoGlide MoS$_2$ nanoparticles showing the effect of organic and inorganic additives

H13 2400 SiC Flat vs. H13 Pin 20 N load, 2 rpm (0.25cm/s), 26 mm track diameter
Minimum Quantity Lubrication (MQL)

- Use of reduced cutting fluids - by 99%
- Flow rate ~ 50 to 500 mL/hour
for Metalworking Fluids

- Using ‘hybrid’ nanolubricant additives in metalworking fluids (oil-based, vegetable oil, and water-based MWF)

Advantages
- Improvement in surface roughness
- Increase in G-ratio
- Spontaneous heat transfer
- Reduction in grinding forces

Oil-based MWF with NanoGlide

Water-based MWF with NanoGlide

* Oversimplified schematic of stable emulsion

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Summary Advantages of NanoGlide

- **Efficient** lubrication: Extend component and lube-drain interval
- **Advanced lubrication technology** for cleaner emissions
- **Non disruptive and insertable** to current fluid technology (potential add-on feature)
- **Multiple fields** of industrial applications (product groups)
- **Sustainable** with positive environmental impact
What the Press Are Saying

NANOMECH RECEIVES NAVY CONTRACT

SPRINGDALE, AR (BUSINESS WIRE) - The Office of Naval Research (ONR) has awarded NanoMec, LLC a contract for the amount of approximately $780,000 to develop the technology of a new nano-lubricant additive called "nanoMach." The "nanoMach" has been designed specifically for improving and enhancing manufacturing efficiency as well as significantly reducing friction and wear in machinery.

The "nanoMach" technology uses a unique, multi-component, composite nanoparticle-based additive that is designed to provide the friction-reducing and wear-reducing properties of a lubricant while also providing the benefits of traditional lubricants. The additive is designed to improve the performance and longevity of machinery and equipment, reducing maintenance costs and improving overall productivity.

The Office of Naval Research (ONR) has a strategic focus on promoting innovation and advancing technology for the defense industry. This contract is a testament to the company's commitment to innovation and its ability to deliver cutting-edge technology that meets the needs of the military.

The contract is expected to be completed in 2012, and it is anticipated that the "nanoMach" technology will have a significant impact on the defense industry, providing a competitive advantage in the design and construction of military vehicles and equipment.

For more information about NanoMec, LLC and their innovative technology, please visit their website at www.nanomech.com.
Thank You!

Let NanoMech’s dedicated team of scientists, engineers, technicians, and management professionals develop advanced lubricant additives for your lubrication needs.

Advanced Nanoparticle Lubricant Additives