RAY TECHNIQUES LTD
Nanodiamonds Technologies

Diamond Nano-Additives for Enhanced Lubrication

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Why Nanodiamonds?

- Nanodiamonds (ND) with the average size of 4-5 nm (10000 times smaller than the thickness of a human hair) perform as nano-abrasives perfectly rubbing the surfaces & decreasing coefficient of friction (COF).

- ND, disaggregated and uniformly dispersed in lubricants, reduce their viscosity, increase thermal stability, improve performance and durability.

- ND, being 50 times harder than steel, are embedded in the friction surfaces creating diamond nano-layer and providing excellent protection against wear and corrosion.

- At high pressure & temperature during lubrication ND turn into Onion-Like-Carbons (OLC) & act as nano-bearings also reducing friction.
ND Structure and Properties

Structure
- Diamond core (gray) with average size of **4-5 nm** with unique properties
- OLC surface structure (black) – lubricating effect
- Surface functional groups (blue, white & red) enabling covalent bonding with lubricant molecules and high stability

Unique diamond properties
- Highest hardness and wear resistance
- Highest thermal conductivity
- High insulating properties
- High chemical resistance
Block-on-ring test: Friction coefficient as a function of time for Rc = 30 block over Rc = 60 ring for pure Mobil 5W30 oil and for the oil with ND additive. Test time is 7 h, load is 30 kg, rotation rate is 200 rpm. ND ratio: 0.03 wt.%
**ND Lubricant Testing in Ukraine**

**End-milling machine**

Gearbox treatment:
- reduced electricity consumption by 12%
- decreased wear by 2 times
- raised the compression to face value

**Combine John Deere 9500**

Engine and gearboxes treating with ND lubricant increased the productivity by 12%

**Compressors NEC**

ND lubricant treating leaded to 10% savings in electricity and significant increase TBO

**Mine Electric Pump D-6300**

ND lubricant treatment saved electricity of 1200 – 1600 kW/hour
Friction Coefficient Testing

Bruker UMT-2 ball-on-plate tribometer

- 15 min: 5% decrease in COF
- 4 hours: 14% decrease

Wear Resistance Analysis:
decrease in scratches
Above: pure lubricant
Below: nanodiamond lubricant
Speed: left- 200 & right- 100 rpm
Decrease in Dynamic Viscosity

Instrument: Brookfield rotary viscosity meter
Samples: BVA68 neat oil, RT-Lub with diverse ND ratio.
RT-Lub sample # 6 with low ND ratio: viscosity decreased by 2 %; RT-Lub sample # 9 with high ND ratio: viscosity decreased by 37%
ND Additives Enter the Market

Tianjin Chanyu Superhard Sci-Tech Co

35 $ / liter

HeYuan ZhongLian Nanotechnology Co

$4.42 - 5.79/100 ml

Xunsn Energy Technology Co

Shenzhen Jingangyuan New Material Development Co

Nano Technology Products (Turkey)

GENCO (South Korea)

Plasmachem (Germany)

Nano-Oil (USA)
Types of ND for Lubrication

1. **ND of detonation synthesis (DND)**
   - Commercially available ND of insufficient quality (low purity and variable surface chemistry)
   - Problematical mixing: non-stable dispersions with sediments
   - Non-transparent additives

2. **ND of Laser Synthesis (RayND)**
   - Patented technology of developed by Ray Techniques Ltd.
   - High purity and controlled surface chemistry
   - Transparent stable colloids without sediments, uniform particle distribution in pastes and gels
Lacks of the Existing Technology

- Polluting & dangerous technology
- ND of non-consistent quality, complicated to use and expensive
- ND composites do not use full potential of ND

- Detonation of explosives (TNT & RDX)
- ND separation & purification by boiling in nitric acid, washing and drying

Image from book of Prof. V. Danilenko. There ND were found in detonation soot in 1963
- Pioneering technology for ND fabrication

- Unique technology for surface modification, disaggregation and dispersion of nanoparticles

- Design of innovative ND composites and ready-to-use ND additives to various materials & processes
RAY Technology of ND Synthesis

The process:
- controllable
- non-dangerous
- environment-friendly
- unique & patented

The main product: monodispersed ND of the highest quality (RayND)

1. Preparation of carbon soot from pure graphite
2. Forming special target from soot & binder
3. Laser treatment of special targets in liquid
4. ND separation by flotation method, washing & drying
RAY has developed an industrial technology (know-how) for introducing ND within various media. Special mechanical, thermal and chemical ND surface modification results in:

- Covalent bonding with matrix’ molecules (no surfactants!)
- ND disaggregation in diverse solvents
- Uniform distribution in water, solvents and oils
- High efficiency of ND in the improving performance of basic material
DLS analysis performed at HU with nanosizer Malvern indicates high level of ND dispersion in water (alone narrow peak at 4.9 nm)

**ND concentration:** 1.7 wt.%

**Results**

- **Z-Average (d.nm):** 73.53
- **Pdl:** 0.488
- **Intercept:** 0.935
- **Peak 1:** Size (d.nm) 4.943, % Number 100.0, Width (d.nm) 1.403
- **Peak 2:** Size (d.nm) 0.000, % Number 0.0, Width (d.nm) 0.000
- **Peak 3:** Size (d.nm) 0.000, % Number 0.0, Width (d.nm) 0.000

**Result quality:** Good

**Single Particles** DLS analysis performed at HU with nanosizer Malvern indicates high level of ND dispersion in water (alone narrow peak at 4.9 nm)

ND concentration: 1.7 wt.%
Benefits from ND in Lubricants

Physical Processes

- Fine polishing and creating surfaces of very low roughness
- Introducing ND particles into a metal surface and creating protective nano-coating film with high wear resistance
- Formation of an onion-like carbon (OLC) structures on the ND surface allowing them to work like nano-ball-bearings, significantly reducing friction

Onion-like carbon (OLC)

Benefits

- Reduced energy consumption
- Easier cold starts
- Decreased noise
- Reduced exhaust gas emission (in the case of an internal combustion engines)
- Enhanced horsepower and airproof capacity of engines
- Increased reliability
- Service life of friction pairs increased by a factor of 2 to 3
RT-Lap Testing Results

- Performance testing was conducted by **Acuitas GmbH** (Switzerland)
- Application: motor bearings (2QTY Kaydon; 180ARO)
- RT-Lap-A (ND antifriction grease) was compared with special lubricating grease Klüberplex BEM 34-132

<table>
<thead>
<tr>
<th>Lubricant</th>
<th>Coulomb Friction, Nm</th>
<th>Viscose Friction, nm/deg/sec</th>
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<tbody>
<tr>
<td>BEM 34-132</td>
<td>3.50</td>
<td>0.070</td>
</tr>
<tr>
<td>RT-Lap-A</td>
<td>1.15</td>
<td>0.003</td>
</tr>
</tbody>
</table>

**Conclusions:**
Treating bearings with RT-Lap-A & RT-Lub has resulted in:
- **Coulomb friction decreased by the factor of 3** (RT-Lap only)
- **Viscous friction decreased by the factor of 23** (RT-Lap and then RT-Lub)
RAY Proposed ND Applications

- Lapping / Finishing
- Running-in
- Maintenance
Proposal to Lubricant Producer

- RAY is looking for partners for the commercialization of its technology & products in the field of lubrication.
- RAY is ready to produce ND additives to lubricants in industrial scale.
- RAY proposes joint development of final ND lubricant formulations - highly efficient and easy in handling.
- Samples of ND lubricating products (additives & pastes) are available for validation by producers & consumers of lubricants.
RAY suggests to Lubricant Manufacturer to test the following products:

1) Modified ND powder

2) RT-Lub, 2.5 wt. % ND oil additive based on PEO (BVA-68), dilution ratio should be defined for specific application (in the rate from 1/25 to 1/100)

3) RT-Lap-A, ND grease for lapping / finishing of precision parts and anti-wear treatment of friction pairs

4) RT-W-10, 10 wt.% water-based ND gel for adding to water soluble lubricants. The optimal dilution should be defined for each application

5) ND additives based on oil / polymer produced by potential partner
RAY Advantages

- Environmentally friendly and non-hazardous technology
- Control of the ND crystal’s dimensions & defects
- Ability to obtain uniform ND of high quality:
  - high purity
  - controlled OLC crystal shell
  - high homogeneity of ND size
  - high homogeneity of ND surface chemistry
- High colloidal stability of ND oil
- Uniform particles distribution
- Low cost in mass production
RAY Executives

- **Olga Levinson**, CEO, co-founder of RAY; M.Sc. in Mechanical Engineering, HU course Business Enterprise training; R&D, Business strategy & management

- **Boris Zousman**, CTO, co-founder of RAY, M.Sc. in Electrical Engineering; main inventor of RAY technologies of ND synthesis, surface modification & applications, expertise in TRIZ

- **Galina Geyzersky**, CFO, BA in economics, certified CPA, expertise in R&D funding programs and financial management
Thank you for your attention!

- **Nanodiamond** edited by Prof. Oliver Williams, RSC Nanoscience & Nanotechnology, London, 2014

- **Chapter 5**: Pure nanodiamonds produced by laser-assisted technique, B. Zousman and O. Levinson, Ray Techniques Ltd.

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