# Ray Techniques Ltd.
# Nanodiamond Technologies

NANO ISRAEL 2016
The 5th International Nanotechnology Conference & Exhibition
February 22-23, 2016

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## Introduction

**Nanodiamonds (ND)**. Carbon nanoparticles with cubic diamond structure in the core, carbon-onion hybrid shell and surface functional groups [1] (Fig.1) enabling interaction with molecules of chosen media & objects considerably improving their characteristics due to the unique properties of diamond.

**ND properties**. Diamond core: highest hardness (167 Gpa {111}) and wear resistance, highest thermal conductivity (2300 W/mK), high electrical resistivity ($10^{13}$ Ωcm), low thermal expansion ($1.0\times10^{-6}$ $K^{-1}$), wide band gap (5.47 eV {300 K}), high refractive index (2.417), low specific gravity (3.52), chemical / radiation resistance and biocompatibility [wiki]; specific ND features: tiny size (< 100 nm, usually < 10 nm), large surface area (250- 450 m²/g); high & controllable chemical activity of the surface.

**ND applications**. Polishing, lubricants, nano-electronics, coatings, adsorbents, catalysts & biomed research [1, 2].

**ND production**. Currently ND are produced by non-controlled technology of explosives (TNT and RDX) detonation (Fig.2). Non-constant ND quality restricts the possibility of implementation & Global Market volume [2].

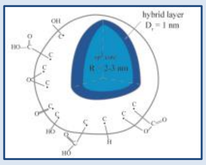


*Fig. 1 ND structure [1]*

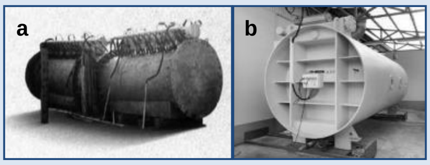



*Fig.2 ND reactors in a) Ukraine, b) Iran*

## Laser ND Synthesis

**Technology**: Developed method, Light Hydro-Dynamic Pulse (LHDP) [3] for fabrication ND by laser treatment of hydrocarbon targets is controlled, non-hazardous and efficient, providing high purity and homogeneity of ND without graphite and metal impurities. The process includes:

A. Forming multi-component targets containing carbon black and wax
B. Laser treatments of targets in liquid
C. Isolation ND by oxidation, flotation, washing & drying

**Advantages:**

1) Controlled process providing ND properties constancy
2) Non-hazardous and environment-friendly process
3) No security requirements and limitations
4) Low cost: the targeted price is less than 1 K $/ kg
5) High quality of ND (Table 1)

| Trait | Analysis | DND | LND |
|---|---|---|---|
| Purity | Incombustible residue | 0.4 – 8.0 wt.% | Non-detected (< 0.02 wt.%) |
| Metal impurities | ICP | Fe, Ti, Al, Ca | Non-detected |
| Carbon impurities | sp2 content by XPS | 74 .4 % surface | 15.5 % surface |
| Average size | XRD, Scherrer formula | 4.3 nm | 4.5 nm |
| Size uniformity | PSD, TEM images | 2-18 nm | 2-10 nm |

*Table 1. Comparison of ND produced by detonation and laser synthesis (DND & LND respectively)*

## Novel Nanodiamond Applications

**Electronics.** The problem of overheating in high power electronics, laser and LED industries is usually caused by a high thermal resistance of insulating polymers. The developed ND-based additives significantly increase their thermal conductivity and improve insulation ability.

Testing: Thermal conductivity of epoxy resin EP 502 CL 0.2 W/m*K to 16.3±0.3 W/m*K ND-BN filler. Breakdown voltage increased twice.

The second important issue is cost reduction by speed-up of wafers and lenses polishing.

**Machinery.** Main challenges in machinery are friction reduction, high reliability and durability of mechanisms and decrease in their weight. ND solutions include additives to coatings, lubricants & composite materials [1, 2, 4].

Testing: ND in the recently developed lapping grease RT-Lap and additive to lubricants Adigriz polish the surfaces reducing the friction; ND introduce within friction surfaces and create protective diamond superficial nano-layer reducing the wear. Service life of mechanisms increases at least tripled and decrease in the friction enables saving of ~8 % the consumed energy (or power rise).

ND has great potential in powder metallurgy (high hardness & wear resistance; low weight of composites).

**Energy.** Besides energy saving and efficiency increase due to anti-wear treatment, ND can be applied in energy storage: catalysts in fuel cells, onion carbon additives to supercapacitors , ND-polyimide dielectric films [5].

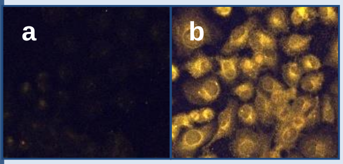
Testing: one of our preliminary tested ND additives to electrolyte of vehicle batteries has leaded to 80 % increase in the service life, to 7 % increase in the capacitance and to high stability of voltage in a standard discharge testing.

**Chemistry**. High potential for polymer industry: ND uniformly dispersed in basic material even in small concentration (<1; wt.%) cause drastic changes in the material characteristics (hardness, wear, chemical and radiation resistance, thermal conductivity, else) [2, 4].

Another ND application in chemistry is highly efficient catalysts, particularly, in styrene production [6] and methanol electro-oxidation.

**Medicine.** Unique mechanical, optical and magnetic properties, tiny size and biocompatibility makes ND highly promising for bio-imaging (Fig. 3), early diagnostics and theranostic applications [7]. ND is a safe alternative to toxic quantum dots. LND in the defined concentration is a strong anticancer agent, not affecting healthy tissue.

Testing: LND in contrast to DND do not cost lymphocyte activation & more suitable for *in-vivo* applications *(Fig.4 [7])*.



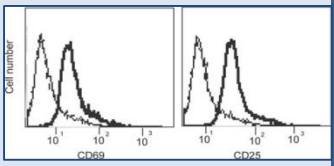




*Fig. 3 (on the left). Panc01 cell line: a) without LND, b) with LND.*
*Fig. 4 (on the right). Immune response, TK-1 cell line, Activation of CD69 and CD25 lymphocytes was analyzed after incubation with DND (regular line) and LND (bold line) of the same ratio.*

**Conclusion**. Joint efforts of academy & manufacturers are necessary for the development and implementation of promising ND applications in industry and medicine.

## References

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