The most prominent feature of nanotechnology is miniaturization. Nano-structures behave differently compared to bulky materials. An insulator may behave as a good conductor, a yellow metal may look red or an inert chemical may behave as a reactive one.

These nano-structures behave differently due to three reasons: (i) Large surface interface to volume ratio, (ii) Size effect and (iii) Quantum effect. These qualities of materials at the nano scale are being exploited in the defence sector also in two major interconnected areas. They are sensors for various applications and nano-energetic materials for propulsion and explosives.

Sensor Applications

Sensors are based on principles of electronics, magnetism and photonics. In miniaturized form they can revolutionize modern war fields. Network centric warfare using C4ISR (Command, Control, Communication, Computer, Intelligence, Inter-operability, Surveillance and Reconnaissance), faster means for digital signal processing and communication, automation or robotic control for reduced manning, uninhabited combat vehicles etc are some applications where nanotechnology is showing promise.

An object bound by nano-wires could be made invisible to naked eyes—stealth technology could get a major boost with this. Better detection sensors and battlefield/soldier monitoring mechanisms can be evolved using nano-sensors.

Detection of chemical warfare agents, buried mines and explosives is one of the major challenges before the armed forces today. A solid-state advanced sensor composed of nano-cluster Metal-Insulator-Metal Ensemble (MIME) has been developed using chemical vapour deposition. The area of application is being further expanded by development and practical implementation of an ‘electronic nose’. These sensors may be incorporated into breathing-air lines, inserted into filters in respirators or into protective clothing, attached to ground scanners for ground-mine detection, mounted on Unmanned Aerial Vehicles (UAVs) or deployed as an array of remote drop-off sensors for battle space information.

Solid-state sensors are attractive because of compactness, robustness, relatively low cost, high position resolution, low power consumption and proportionality of signals to incident particle energies. However, they lose sensitivity at low particle energies. For such applications, novel sensor concept is needed. Trajectory sensor is one such concept. Trajectory sensor is a generic name for all those sensors that measure or characterize particles. In dispersion sensors, particles are subjected to electric or magnetic field, which separate particles trajectory based on energy, velocity and mass of the particle. Sometimes sensors based on time-of-flight are employed, especially for high-signal situations.

Electronic devices are being miniaturized using nanotechnology. In addition, conjugation of bio-organics has also been attempted for sensor application. Since nano-materials behave

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The major impact of nano-materials is felt in the area of warheads, pyrotechnics and propulsion devices. The conventional micro-scale powders are replaced by counter nano-materials to ensure compositional similarity on the one hand and enhanced performance on the other.

An object bound by nano-wires could be made invisible to naked eyes.

Conventional solid rocket propellants as fuel, density enhancer, and combustion-instability suppressant can also act as burning rate raiser, if used in nano-form, due to short diffusion path length in burning. A rise of around 200% is also reported and a faster burning rate means higher energy release and higher velocity of rockets/missiles. Significant improvement in burning rate is also observed by incorporating nano forms of conventional burn rate modifier iron oxide and conventional oxidizer ammonium perchlorate. In explosives also, nano-form of aluminium has shown significant improvement.

Since processing such high-end materials is hazardous due to their inherent application, they are prone to burn, explode or release heat if stimulated by friction, drop, spark, or electrostatic discharge. The development of insensitive munition (IM) is the order of the day, so that they become less sensitive to such external stimuli, but at the same time deliver the same energy. Nano-materials are blessings in disguise and they reduce the sensitivity of such materials and compositions to external stimuli without compromising the yield and performance. That is why, the nano form of RDX is aptly referred as RS-RDX (Reduced Sensitivity RDX).

In pyro-devices, thermite charges are widely used for quick release of energy and incorporating nano iron oxide leads to significant rise in their ignition and energy release parameters. Nano-materials have percolated into the area of thermal insulation coating also. They give uniform coating and improve insensitivity properties. Protection of gun barrel used coating of titanium oxide (TiO₂) and in nano-form can provide high UV alternation, resist deterioration and fading in guns. Stealth coating on aircrafts and corrosion resistant coating for naval ships has also been developed using nano-materials.

Nano-energetic materials (NEMs)

The defence sector is based on the principle of ‘destruction and neutralization’. The power of materials used in the defence sector is enhanced by the use of nano-materials. Nano-composites based on conventional polymers can work in that adverse or alien environment where use of polymers cannot be thought of. The polymer degradation mechanism changes and effects of thermo-oxidative, reactive-oxidative, UV-electron radiation environment are nullified.

In any chemical reaction, inhomogeneity on the surface of materials acts as reaction sites. These reaction sites are localized at nano-meteric scale and thus ignition properties are much enhanced. Additionally, replacing micrometric materials by nanometric materials may lead to higher surface area for same volume of material. Surface area dependent properties like burning rate of compositions improve with such replacement.

The major impact of nano-materials is felt in the area of warheads, pyrotechnics and propulsion devices. The conventional micro-scale powders are replaced by counter nano-materials to ensure compositional similarity on the one hand and enhanced performance on the other. The incorporation of energetic materials in nano form leads to rapid and controlled release of energy and may improve ignition, propulsion and explosion parameters. Due to their capability to tailor energy release and impulse management, NEMs are essential ingredients of modern Thermobaric Weapons. Higher energy densities and explosive yields compared to conventional composition are ensured.

NEMs may be nano-fuels, nano-oxidisers or nano-explosives. In propulsion applications, the nano-form of conventional solid powders like aluminium, magnesium, boron, ammonium perchlorate, iron oxide etc are tested and significant improvement is observed in performance. Aluminium, which is used in conventional solid rocket propellants as fuel, density enhancer, and combustion-instability suppressant can also act as burning rate raiser, if used in nano-form due to short diffusion path length in burning. A rise of around 200% is also reported and a faster burning rate means higher energy release and higher velocity of rockets/missiles. Significant improvement in burning rate is also observed by incorporating nano forms of conventional burn rate modifier iron oxide and conventional oxidizer ammonium perchlorate. In explosives also, nano-form of aluminium has shown significant improvement.

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The multi-disciplinary domain of nanotechnology must be augmented to help defence forces serve better by making them light but lethal.

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