TECHNOLOGY FOCUS

BULLETIN OF DEFENCE RESEARCH & DEVELOPMENT ORGANISATION

ISSN : 0971-4413 Vol. 15 No. 6 December 2007

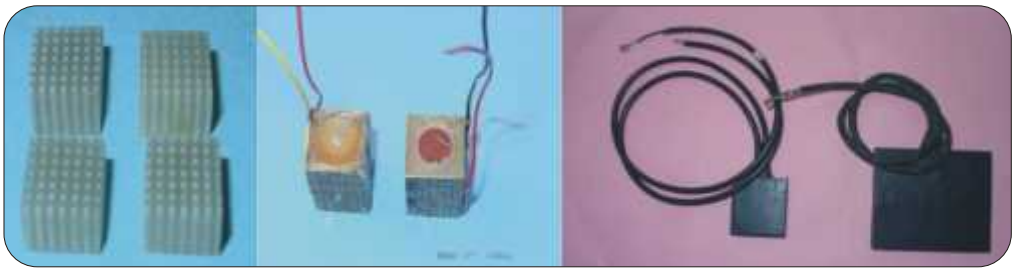
SPECIAL MATERIALS FOR NAVAL APPLICATIONS

DRDO has a strong base for development of special materials and products for naval applications and has developed naval materials and technologies for import substitution, protection of underwater hulls against corrosion and fouling, and also for monitoring of harbour water. It has achieved noticeable growth in areas such as high capacity fuel cell, speciality polymers, processing technologies for metals and ceramics, advanced protection technologies, and chemical and biological means of environmental control. Besides, quite a good number of advanced analytical and processing facilities have also been created to facilitate further and faster growth of the development of R&D efforts towards fruition.

Core competence of DRDO in the field of special materials is the development of special processing technologies for polymeric, metallic and ceramic materials and their characterisation; development of fuel cell power packs; development of advanced protection technologies for structures in marine environment; chemical and biological control of marine environment; and failure investigation of structures and components in marine environment. Some of these products/technologies have been covered in this issue of *Technology Focus*.

CERAMICS AND COMPOSITES

Piezocomposite Transducers



Left to right: Piezocomposite transducer elements, 4-element piezocomposite stacks, and piezocomposite hydrophones

DRDO has developed piezocomposite transducer elements for hydrophone and projector applications by precision dicing technique. The piezocomposite hydrophone arrays and piezocomposite acoustic projector have improved acoustic detection and ranging, and enhanced resolution and imaging of the target. The possible application areas of

MESSAGE

Naval Materials Research Laboratory (NMRL) is the identified single window for providing technology solutions in the area of marine materials to the Indian Navy. Keeping in view the diverse needs of the Naval fleet, the laboratory has been working in thrust areas like underwater marine materials technology, stealth, energy-sources conversion technologies and devices, protection technologies for marine environment, smart materials and soldier-comfort technologies in a focused manner. The technology of advanced materials being multidisciplinary in nature, the laboratory has organised itself to perform cutting edge research and development activities in the discipline of ceramics and composites, polymers, energy science, marine materials protective technologies and marine biotechnology.

In several areas, science and technology activities have matured into product development, and as many as 30 technology transfers have taken place from the laboratory to industry during last five years. Over 200 publications and 40 patents proudly owned by the laboratory stand testimony to the quality of research and development being pursued by it.

It is well appreciated that several of the base technologies developed have found important spin-offs for application in other sectors of defence and civilian society at large.

It is only appropriate that this issue of *Technology Focus* is dedicated to consolidate and highlight the recent achievements and accomplishments of NMRL in the filed of cutting edge materials technologies.

(Dr A Sivathanu Pillai)
Distinguished Scientist &
Chief Controller (R&D)

piezocomposite transducer elements include flank arrays for submarines, side scan sonars working at different frequency ranges, mine hunting sonars, large area hydrophone arrays, torpedo nose cone transducers, etc. The transducers elements have improved the detection capability of the targets.

PMN-PT Ceramics

Pyrochlore phase is detrimental to the dielectric and piezoelectric properties of PMN-PT ceramics. DRDO has developed a novel, cost-effective, indigenous powder processing route which in turn leads to PMN-PT ceramics free from pyrochlore phase. Two ceramic compositions with excellent piezoelectric and electrostrictive properties, respectively have been developed for applications like transducers, hydrophones, futuristic sonars, multi-layer actuators, etc.

PMN-PT ceramics

SOFC Materials

Solid oxide fuel cell (SOFC) has emerged as a leading device to provide clean and efficient power for the future. SOFC can be used with a wide range of hydrocarbon fuels. Due to its high operating temperature, NOx and SOx emissions from the SOFC materials are considerably low. YSZ electrolyte, Ni-YSZ cermet anodes, LSM cathode, LSC, LCC interconnect and lanthanum-strontium-borate-based glass sealant materials have been developed by DRDO using various chemical methods such as spray drying/pyrolysis, combustion synthesis, polymeric precursor route, and standard glass forming techniques. Property evaluation of YSZ for electrolyte and LSM for cathode applications has been carried out. These SOFC materials have been found suitable for the fabrication of SOFC unit cell.

TZP Ceramics for Structural Applications

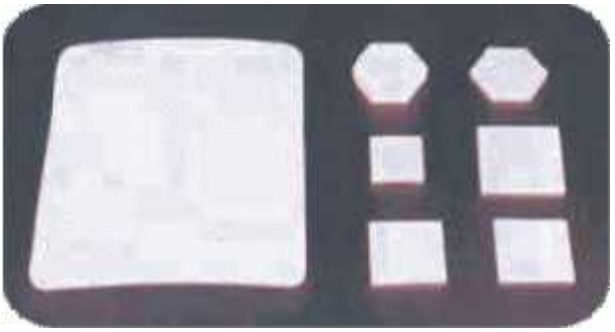
DRDO has developed technology for the preparation of ultrafine, pure and homogenous yttria- and ceria-doped zirconia powders of different compositions. Tetragonal zirconia polycrystalline ceramics (TZP) prepared from these powders have high strength and high fracture toughness because of characteristic transformation toughening behaviour of these materials. Fracture toughness values of 11 $MPam^{1/2}$ and flexural strength values of 1200 MPa have been obtained for yttria-doped zirconia ceramics. For ceria-doped zirconia ceramics, fracture toughness values as high as 25 $MPam^{1/2}$ and moderate strength values of 750 MPa have been achieved by conventional compaction and sintering techniques. Due to their improved mechanical properties, these materials have extensive use in high temperature structural applications.

TZP ceramic components

Zirconia-Toughened Alumina Ceramics

Alumina ceramics are extensively used as structural materials, but their low mechanical properties limit their applications in the modern technology. To enhance their mechanical properties, more energy absorption mechanisms are needed. Micro-cracking, crack-tip shielding, crack branching, and crack deflection are the

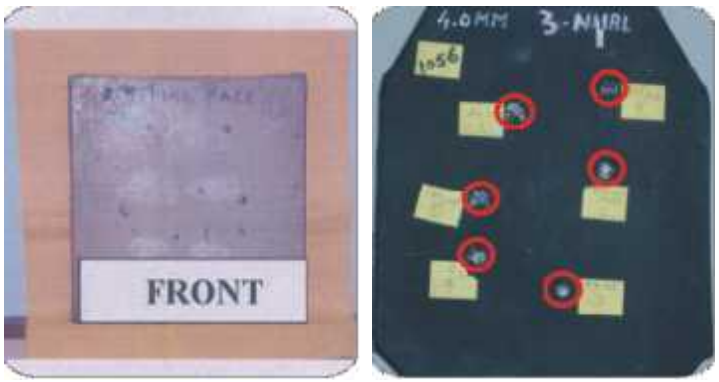
mechanisms available for above reinforcements. Introduction of stress induced t → m transformation process by incorporating tetragonal zirconia ceramics in alumina matrix has improved mechanical properties of resultant composite ceramics considerably. Fracture toughness and strength of zirconia-toughened alumina (ZTA) ceramics are thus significantly higher than pure alumina. ZTA ceramics have extensive use in body and vehicle armours, cutting tools, wear resistant, and high temperature structural applications because of their low cost and excellent mechanical properties.



Zirconia toughened alumina ceramics

DRDO has synthesised ZTA powders by an innovative semi-wet process of spray drying slurry of fine alumina powders in Y-Zr nitrate solution. ZTA ceramics obtained from these powders have hardness of 15.5 GPa, fracture toughness of 8 $MPam^{1/2}$, which is almost twice that of alumina ceramics, and flexural strength of 550 Mpa. The technology has been transferred to industry.

Body and Vehicle Armours



ZTA composite body and vehicle armour before (left) and after ballistic testing (right)

Weight, flexibility, and cost determine the wearing comfort and affordability of body and vehicle armours. DRDO has developed special ZTA ceramics, high-strength polymer blends, and composites and adhesives, which can be used for body and vehicle armour. The ZTA has emerged as a superior choice because of its lighter weight; extreme hardness and high strength; fracture toughness; modulus of elasticity; temperature, corrosion and erosion resistance; and chemical inertness, which contribute towards its ability to withstand new sophisticated weapons that have higher kinetic, and thermal/chemical energy levels. It is also cost-effective and easy to fabricate.

While the typical body armour has an aerial density of 28 kg/m^2 the vehicle armour has an aerial density of 40-45 kg/m^2 and 90-96 kg/m^2 depending upon the application need. Both armours have shown multi hit capability as per international standards and are among the lightest when compared with all indigenous armours available in the country.

Blast Resistant Composite Panels

Mines are threat for tanks, and defence and civil vehicles. DRDO has developed composite panels made of especially modified resins and special glass fabrics, which are very light and can withstand high explosive blast and absorb shock waves of the mines.

Blast resistant composite panels before (left) and after testing (right)

POLYMERIC MATERIALS

Polymeric Rubbing Fenders

Polymeric rubber fender

Rubbing fenders or rubbing stakes are usually made of teak and fitted on hull of ships to protect the hull structure from impact damage during harbouring. But these fenders often get damaged during impact with concrete/steel, etc. and have short life in marine environment. DRDO has developed polymeric rubbing fenders as a better substitute for teak.

The material is a combination of polymers, has both rigidity and resilience, longer life in marine atmosphere (>10 years), and zero maintenance during service life. The item has been inducted into the Indian Navy, and the technology has been transferred to industry.

Poly-LIST Dock Blocks

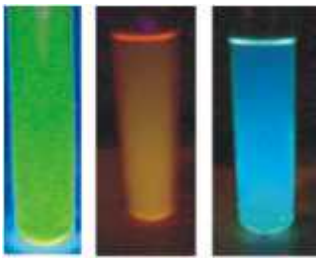
DRDO has also developed reusable Poly-LIST dock blocks as a substitute for teak used for dry-docking of ships. The material is a composite having lightweight metallic structure embedded in a combination of polymers. The blocks have high compressive strength (12 MPa); adequate shear strength (6 MPa); low creep; enough resilient to take the contour of ship bottom; low density (0.85 g/cc); and better vibration damping capability compared to teak. The item has been inducted into the Indian Navy, and an international patent has been filed for the product. The technology has been transferred to industry.

Poly-LIST dock blocks

Polymeric LED material

LED materials are superior to LCD (liquid crystal display) materials in respect of displaying ability. They also function without background light. Polymeric LED materials of multiple colour displaying ability can be tailor made by designing different chemical structures of polymers. In addition, these materials have also potential of visual camouflaging.

DRDO has developed polyphenylene vinylene (PPV)-based polymers and characterised their luminescence characteristics. LEDs with ability of displaying different colours have been composed by varying the co-polymer compositions. Device fabrication using these PPVs as active material is in progress.



Photonic excitation at 365 nm of the LEP solutions

Passive Acoustic Materials

A class of passive acoustic transparent, reflecting and absorbing materials has been developed for diverse underwater applications.

Polymeric Holographic Data Recording Media

Certain liquid crystal (LC)-polymers find application as optical data storage and switching devices. LC moiety and its orientation control the optical data recording ability and can be used as a holographic recording media. Several LC-polymers have been synthesised for specific wavelength range for holographic applications. Stability of such polymer is a key feature for this requirement. Efforts are being made to synthesise polymers having higher temporal and thermal stability.

Conducting Polymer-based Super Capacitor and Battery

Conducting polymers find application in super capacitors and batteries with high energy densities. These devices are required for systems where high-energy throughput is required in short time; pulse sonar and hybrid fuel cell are few examples. Polyaniline and polythiophene have been synthesised and used in fabricating unit cells as well as stacks where SPE has been used as an electrolyte. The performance of the capacitors and batteries are under evaluation for long-term service.

Polymer Membranes for Gas Separation

Removal or purification of gas from toxic or undesirable gases such as CO, CO_2, NOx, etc. is critical for many applications. Separation of CO_2 from hydrogen for fuel cell and air inside submarine are few examples. Membrane-based separations are efficient, less energy consuming and environmentally safe. The design of the polymeric membrane is very critical with respect to solubility and diffusivity of the gases in a mixture. These two factors together decide the perm selectivity of the membrane. For separation of CO_2 from hydrogen for fuel cell, radiation induced grafted FEP-styrene and FEP-VP membranes with very good selectivity have been developed. Work is in progress to develop membranes for purification of air in confined submarine compartments.

High Performance Adhesives

Adhesives for joining metal to cured rubber and layers of rubber tiles are important for acoustic insulation, damping down of pipe, and structural vibration. DRDO has developed epoxy and rubber-based adhesives for joining rubber to rubber and rubber to metal. While an epoxy-based adhesive is a two-component system, the rubber-based is a single-component system. The peel strength for epoxy adhesive is about 12 kN/m and that for the rubber adhesive is about 2 kN/m. The adhesives are excellent for adhering rubber sheet to metallic structures, e.g., pipe insulation and for joining rubber to rubber sheets like multilayer mats. The technology has been transferred to industry.

Levelling Putty

Levelling putty is a most effective way of building metal layers by joining irregular surface profiles, and as a precoat for joining metal to rubber for rubber lining. Epoxy-based putty has been developed for levelling of surfaces and filling the gaps between metal to metal joints and for adhering rubber to metal surfaces.


Failure pattern of putty

It is a two-component system having high strength with desired flexibility (toughness) and can be applied

easily by putty blade to level any undulation on surface with excellent bond strength (>5 Mpa). The technology has been transferred to industry.

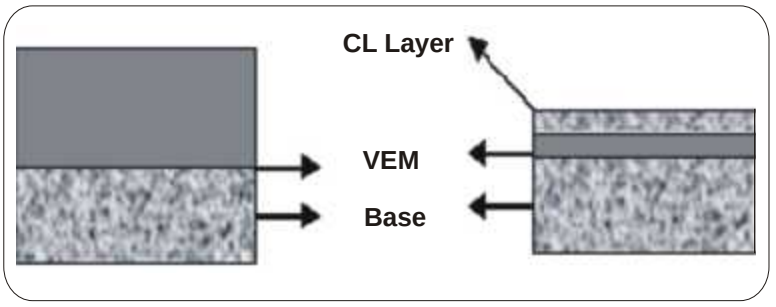
Polyurethane Sealant

Elastomeric sealants are used to seal the gaps in lateral joints of rubber, metal, etc. in a flexible system to provide identical flexibility and leak proof sealing. Conventional polysulphide sealants have low strength, less durability and are hazardous to health. A polyurethane sealant has been developed for sealing gaps between rubber to rubber and rubber to metal articles. The sealant can be used in marine environment for its excellent seawater resistance and ageing characteristics. It is a two-component, having high tensile properties (>7 Mpa; per cent elongation >300), cold curing liquid system.

Failure pattern of rubber adhesive to metal using PU sealant

Materials for Vibration Damping

Damping down of structural vibrations is essential in all engineering applications where rotating machineries are used. The vibrations reduce the fatigue life of machines, platforms, and also results in undesirable radiated noise in the surroundings. In some cases like ships and submarines, the vibrations of hull radiate noise to the sea giving a distinct acoustic signal to the enemy sonar. Rubber materials have excellent damping down properties and are known to be effective in two configurations: constrained layer damping (CLD) and unconstrained layer damping (UCLD). While CLD system uses a thinner elastomeric material as a sandwich between the substrate and the constraining cover layer, the UCLD uses only a thick elastomeric layer on the substrate.



UCLD CLD

UCLD and CLD systems for various metallic and composite structures have been developed and extensively evaluated for the various substrates. The elastomeric material of these systems is especially designed to damp vibrations in wide frequency range when applied on mild steel, aluminium or FRP composites. Material and application technology for each vibration case has been studied and standardised.

Syntactic Foam

Syntactic foams are relatively high density (0.40–0.80 g/cc) foam materials made of ceramic or polymeric microballoons and thermoset resins. Unlike polymer-based foams, these have very high compressive strength and very low friability, good acoustic properties, and better thermal stability.

A series of such syntactic foams have been developed for applications as transducer backing material, and high-strength floats for unmanned underwater vehicles. These can also be used as lightweight sandwich core materials for composite radoms, windmill blades, durable lightweight doors, and window sandwich panels. The density range of these syntactic foams varies from 0.40–0.66 g/cc. Their compressive strength varies from 10 to 22 MPa depending on the density and type of balloons.

Rubber Nanocomposite

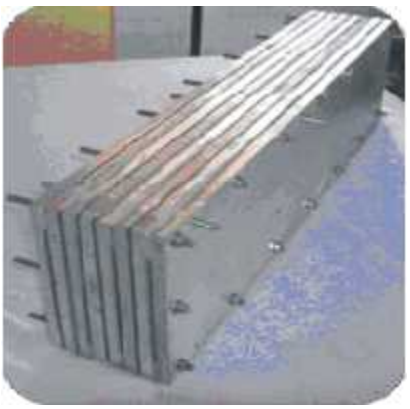
Rubber bushes are essential and critical components of many machines. These bushes are subjected to a high shear stress at variable temperature form sub-zero to even 70 °C during operation. This can result in failure of the bush or failure in adhesion with the metallic components. Dynamic endurance is therefore the most important aspect of such bushes.

A novel nanocomposite rubber bush has been developed by DRDO. The material has ultimate tensile strength of about 29–30 MPa; tear strength of 60–70 N/mm; dynamic mechanical endurance without failure of adhesion or cohesion; thermal stability up to 380 °C, adhesion bond strength of 30–34 N/mm; and excellent ageing properties.

ENERGY SYSTEM TECHNOLOGIES

Planar Reformer

DRDO has done extensive work in the development of various hydrogen generation technologies. Steam-methanol reforming, a well known technology, has been adapted for H_2 generation for field applications.



A planar methanol reformer has been developed by DRDO for mobile fuel cell power plant for generating hydrogen on board a ship from methanol and water. This state-of-the-art technology offers maximum contact area between exothermic and endothermic compartments of the burner and reformer sections so that compactness and high thermal efficiency is achieved. Its modular nature offers easy scale up to any capacity and has wide turn down ratio with quick start up.

Salient Features

Capacity	:	40 lpm H_2 (~74 per cent purity, dry basis)
CO	:	< 1 per cent
Methanol consumption (without heat recovery)	:	1.2 l/hr (reforming) 0.3 l/hr (combustion)
Start up time from cold	:	20–25 min

DROF-Cell

PAFC stack

DRDO has developed Defence Research Organisation fuel cell (DROF-cell) an on site, silent and continuous power plant with very low thermal signatures. The power plant is modular in nature and has very high efficiency.

DROF-cell comprises a 1 kW phosphoric acid fuel cell (PAFC) stack, a planar reformer, power electronics, and necessary control systems. Methanol is pumped to the planar reformer along with water to form hydrogen-rich product gas. The endothermic heat required for reforming is generated by catalytic burning of part of the methanol at low temperature inside the unit. Subsequently the hydrogen-rich gas is fed to PAFC stack to generate power in the form of

unregulated dc. This unregulated dc voltage output is stabilised and converted into desired ac/dc form at required voltage level using power conditioners. The process parameters of the reformer, fuel cell and power conditioners are controlled by a PLC.

A 2 kW DROF-cell

Salient Features

Capacity	:	2 kW
Output	:	230 V ac
Weight	:	~ 150 kg
Fuel	:	Methyl alcohol

Other Options

Capacity	:	1–10 kW (modular)
Output	:	Stabilised dc output (any fixed voltage)/230 V ac
System	:	Low instrumentation option for special requirements like signal outposts

10-kW Skid Mounted System

The system consists of phosphoric acid fuel cell stacks and planar methanol reformer integrated with power conditioner and control systems. The system takes advantage of modular concept for fault isolation and ease of operation and maintenance. The trolley can be moved to any location and made operation ready in 2 hr. The system is silent and emission free and suitable for on site applications in remote areas.

10-kW skid mounted DROF-cell

Salient Features

Power output	:	230 V ac, 1φ, 10 kW
Feed	:	Methyl alcohol, water, air
Exhaust	:	Water, CO_2

PROTECTIVE TECHNOLOGIES

Self-stratifying Coating

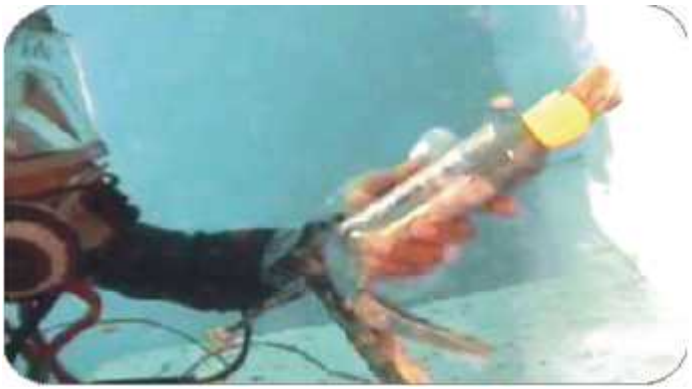
DRDO has developed self-stratified coating for one coat application on naval structures. It is a blend of two paint compositions comprising titanium dioxide pigmented silicone modified soya alkyd, a high performance exterior paint, and red iron oxide pigmented epoxy resin, a primer. After application over substrate surface, it separates into two coating layers. The titanium dioxide pigmented silicone alkyd resin paint migrates to air interface whereas iron oxide pigmented epoxy resin towards substrate interface. Separation takes place within 30 min of application. It takes 12 hr for surface drying of applied paints over a given substrate.

This coating imparts both the properties of individual paints. It also eliminates the inter-coat adhesion failure leading to increase in service life of the applied coating. Its mechanical properties, adhesion strength, and durability against outdoor exposure are also excellent.

Paint for in situ Underwater Application

The in situ paint composition is solvent free two-pack system comprising titanium dioxide pigmented epoxy resin for instant on site repair/maintenance of submerged objects. Paint can be applied by a brush. It adheres to the substrate by replacing water present over the substrate surface.

Applied paint takes 2 hr to form a coating layer under immersed conditions without requiring the structure to bring into dry condition.



In situ underwater painting on ship hull

Thermal Spray Organic Coating

Thermal spray organic coating is done by thermally-induced liquification of pigmented thermoplastic polymeric compositions and subsequent deposition on substrate by flame-spray technique. These coatings are solvent-free compositions and have long shelf-life. The development work on this coating includes, grafting of maleic acid on low-density polyethylene (LDPE) in order to improve its adhesion over mild steel surface. The modified LDPE has shown better adhesion and anticorrosive properties.

Active Shaft Grounding

Active shaft grounding (ASG) works to reduce the extremely low-frequency electromagnetic (ELFE) signatures that originate from modulation of current passing through a ship's shaft and shaft bearings.

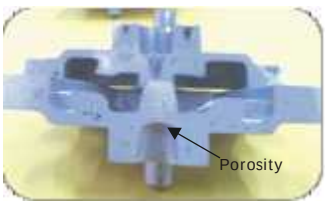
It uses electronics to ground the shaft at times when the bearing resistance is high. The system measures the shaft-to-hull potential through a slip ring assembly, and then uses this signal, after amplification, to control a high current power supply that draws current out of the shaft through a second slip ring assembly. Variation in the resistance between the shaft and the hull through the bearings is actively compensated for and the resulting ELFE signatures are eliminated.

MARINE MATERIALS

Near-net Shape Casting

SSM cast A356 thick section pistons

DRDO is working on an emerging technology area of semi-solid metal processing (SSM). The process involves forming of near-net shaped metal parts using semi-solid raw material that has a unique non-dendritic globular microstructure. Semi-solid slurries with globular particles exhibit thixotropy, a physical state wherein solid metal behaves like a fluid when a shear force is applied. This unique feature of semi-solid slurries is exploited to inject them into pressure die casting dies (christened



Porosity in liquid die cast component

SSM cast sound component

as thixocasting) to produce high-integrity defect free pressure tight components. Several thick and thin intricate near-net shape aluminium alloy components such as piston, thin blades, pump cover, etc. have been fabricated using semi-solid metal processing technology. Thixocast aluminium alloy components can be potential candidates to replace steel or cast iron components to achieve considerable weight reduction.

Flameless Heating Device

At high altitude engine start-up is a problem in winter when the atmospheric temperature drops down to -20 ^{o}C and below. Conventional ways of warming diesel tank gives rise to smoke and fire, which is not only dangerous, but may also leave signatures to be detected by enemy.

Left to right: Heating pouch; Al foil bag containing heating pouch; and heating pad wrapped around diesel tank

DRDO has developed an electro-chemically reacting alloy powder composition for warming applications in adverse conditions. The composition is an alloy of Mg, Al, and Fe powders, which reacts electrochemically in the presence of electrolyte and produces 1012 kJ/g heat. It can be used as a non-electrical, portable, flameless instant heating device for warming food packets or diesel engine tanks, machinery, etc. in cold climatic conditions.

Welding Consumables for Ship Building

DRDO has developed welding consumables and welding technology for high strength structural steel like indigenous DMR-249A for ship building application. Weld consumables have been developed for MMAW (manual metal arc welding), FCAW (flux core arc welding), GMAW (gas metal arc welding) and SAW (submerged arc welding) processes.

After satisfactory user trial at Cochin Shipyard Ltd, Kochi and Garden Reach Shipbuilders and Engineers, Kolkata these welding consumables have been inducted into the Service. The technology has been transferred for the production of alloyed core wire for SAW and GMAW process to industry.

GMAW alloyed wire

SAW alloyed wire

MARINE BIOTECHNOLOGIES

Arsenic Removal Water Filter

Effects of arsenic present in water are severe and cause of skin cancer, carcinoma, stunted growth, etc. To mitigate the problem of arsenic contamination, a novel cost-effective technology has been developed. This technology is based on the principle of co-precipitation and adsorption.

Salient Features

- Suitable for household use even without power.
- Environment-friendly, easy to operate and maintain.
- Easily available reactant materials.
- Flow rate: 15 lph and 30 lph.
- Filtered water quality as per WHO/EPA drinking water standards.
- Waste utilisation in the form of non-leachable M-25 grade cement bricks.

The field trials of the filter have been successfully completed in the arsenic-affected villages of West Bengal. An international patent has been filed and the technology has been transferred to three entrepreneurs including an NGO.

Arsenic removal filter

Autocontrolled Carbon Dioxide System

Autocontrolled CO_2 system

The system helps in containment of CO_2 in closed compartments of tanks, submarines, and aircraft. It employs inert absorbent, which makes it suitable for easy and safe handling. The adsorbent is regenerative and non-consumable, hence economical. The system comprises an online CO_2 monitor, which continuously monitors the levels of CO_2 in the compartment. It initiates the adsorption system when the levels of CO_2 reaches to predefined levels or 0.5 per cent (v/v) and puts off adsorption system when the levels of CO_2 fall to 0.03 per cent or to predefined levels. After saturation of adsorbent, the auto controller puts the system in regeneration mode where CO_2 is expelled out and the system becomes ready for the next cycle of adsorption. The system has been vigorously tested by the users and has exceeded the technical requirements.

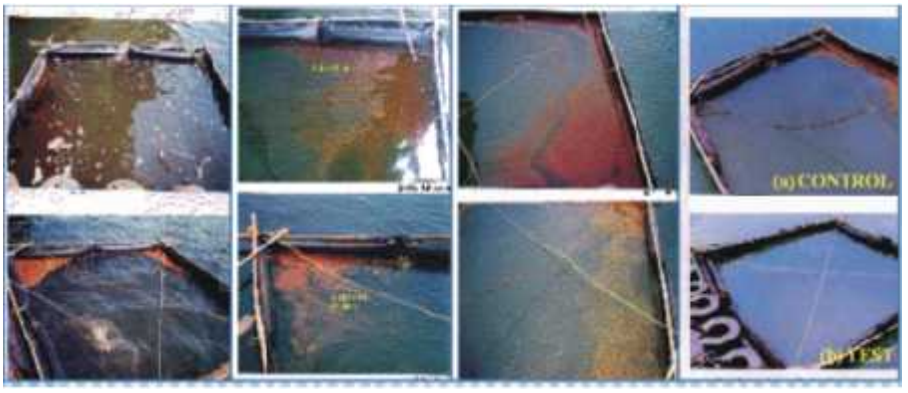
Air Purifier with Negative Ion Generator

The system comprises three stages—pre filter, HEPA filter, and activated carbon filter—air cleaning technology for purifying contaminated air. The polluted air is mixed with negative ions, which helps in fighting the bacteria and thereby relieves stress induced problems like headache, insomnia and migraine. The purified air in turn increases concentration and thus helps in overcoming premature fatigue. Performance evaluation of the system has been satisfactory. The system is ideal for air conditioned places where polluted air re-circulates and causes various diseases. The system can be useful in closed compartments of ships, submarines, tanks, auditoriums, and hospitals, etc. where pure air is a pre-requisite.

Bioremediation of Oil

Fuel oil hydrocarbon pollution in marine environment is known to affect man, material and marine ecosystem. These hydrocarbons are known to cause permanent inheritable changes to exposed individuals leading to increased incidents of cancer, allergies, asthma as well as bacterial and viral diseases. DRDO has developed an ecofriendly approach for such oil spill management.

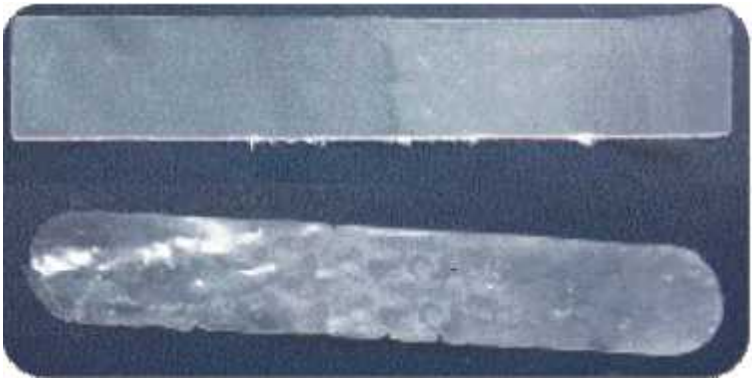
The bioremediation of pollutant oil using DRDO developed technology can be managed by spraying bio-emulsifier, oil degrading marine bacteria, and nutrient mixture at polluted site in three days intervals for complete removal of oil. The oil hydrocarbons are degraded by bacterial alkane mono-xygenases and associated enzymes releasing CO_2 and water without using any toxic substance. The other bio-molecules get assimilated as biomass and Bioemulsifier as byproducts. Bioemulsifier is a surface active biomaterial, which facilitates emulsification of oil in water increasing entry of bacteria in oil layers, enhancing bioavailability of oil for biodegradation in ecofriendly manner.



Bioremediation of floating oil in seawater (area 25 m^2) using biomulsifier hydrocarbon utilising bacteria and nutrient compound. The trial indicated fast and complete dispersion of oil in test boom as compared to control within 10 days

The bioemulsifier reported here is a heat stable compound, TGA (initial decomposition temperature 192 ^oC), having a molecular weight of ~5000 and 16 fatty acids, which help in its surface active properties.

Bacterial Degradation of Polyethylene



LDPE films before (top) and after (bottom) treatment with PE degrading bacteria

DRDO has also identified low-density polyethylene (LDPE) degrading bacteria, viz., Bacillus cereus, B. halodenitrificans, and B. pumilus by gene sequence analysis. These bacteria degrade LDPE through their metabolic enzymes.

The degradation involves oxidation of polymer mediated by the intra-cellular as well as extra-cellular oxidative enzymes produced by the bacterial cells. The process finds application in solid waste treatment of industrial and municipal waste.

Ecofriendly Removal of Coatings from Beverage Cans

The process involves immersion of flattened can strips in a nutrient medium containing a consortium of bacteria capable of utilising polymeric coatings. The bacteria used for the process has been isolated from a local stream highly polluted with industrial waste water which predominantly contained genus Pseudomonas and Bacillus.

The biological degradation takes place by enzymes, which facilitate environmentally safe biodegradation of such polymeric coatings thus offering an ecofriendly, cost-effective, and energy efficient process.

Potable Water Analysis using DNA Microarrays

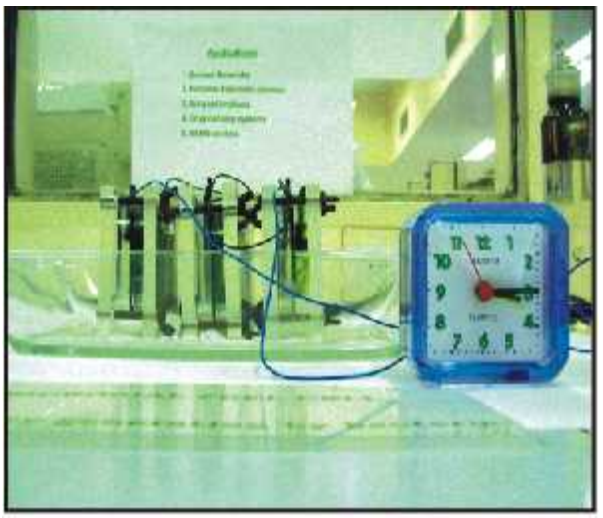
Water-borne pathogens are hazardous therefore their early detection is of utmost importance. Early detection of E coli as an indicator of water quality is an established parameter. Detection methods and devices are being developed using fibreoptic biosensors (antibody and nucleic acid probe-based), and DNA chip-based systems.

Bacterial Electricity Generation

Bacterial conversion of chemical energy, derived from carbonaceous substrates, to electrical energy takes place through microbial catalysts called enzymes. Unlike chemical fuel cells, the biological fuel cells operate under ambient temperature, neutral pH, and normal pressure.

Bacteria switch from the natural electron acceptor such as oxygen or nitrate to an insoluble acceptor such as the fuel cell anode. This can occur either via membrane-associated components or soluble electron shuttles. The electrons then flow to a cathode at which the electron acceptor is reduced.

Microbial fuel cells have been designed using both aerobic (Bacillus sp.) and anaerobic (Desulfovibrio sp.) bacteria. Open circuit potentials of 350-450mV and 650-750mV, respectively have been realised.



Clock running on microbial fuel cell based on anaerobic bacterium Desulfovibrio sp.

Biodegradation of Polyurethane

A potential polyurethane (PU) degrader Bacillus pumilus NMSN-1d that produces enzymes like lipase and esterase has been characterised.

The B. pumilus NMSN-1d isolate is useful as a biological tool for bioremediation of landfill sites contaminated with PU waste. PU-based paint formulations can also be used effectively for removal of surface coatings.

TEST & EVALUATION FACILITIES

DRDO has also established test facilities to carry out the various testing and validations required for the realisation of the technologies and products. Some of the unique facilities established by DRDO are:

XRF Spectrometer: XRF spectrometer (model: MDX1000) allows simultaneous quantitative multielement analysis of a wide range of samples using WDX technique. The instrument can analyse the following elements: Zr, Y, Al, Si, Mg, Nb, Fe, Sr, La, Cr, Pb, Ti, Ni, and Mn. The instrument is used for analysing purity of liquids, powders and solids containing above elements from 10 ppm concentration onwards. The operating procedure of the instrument is very simple, and at a time maximum 10 channels can be utilised.

Temperature Programmed Desorption Reduction Oxidation (TPD/R/O): The product is used to define

the strength, the number and the type of active sites available on the surface of a catalyst by the determination of the quantity of gas desorbed from the fuel cell electrocatalyst submitted to a linear temperature ramp. TPD/R/O allows the determination of the gas quantity (H_2, O_2, CO, etc.) chemically observed from the surface of a solid sample at various temperature profile. The instrument can be used to characterise samples like heterogeneous catalysts, metal corrosion, measurement of acidity and basicity of surfaces and reducibility (oxidability) of materials, and also for evaluation of temperature range in which a sample undergoes oxidation due to an oxidising agent.

FTIR Chemical Imaging: The Fourier transform infrared spectroscopy (FTIR) instrument is used to characterise coating film; to study the modification of commercially available polymers by chemical route to be used as binder for paint formulation; for failure analysis of coating film; self-stratified coating; to study the curing kinetics of underwater applicable paint composition; in self-healing coating characterisation, etc. The instrument can be used for analysing wide range of organic compounds like resins, polymers, biological samples, medicines, etc. Chemical imaging provides additional information by way of the acquisition of spatially resolved spectra. Detection limit for chemical imaging is quiet different than for bulk spectroscopy. Bulk spectrum represents an average of the material present. Hence, spatial signature of trace compounds are simply missed due to dilution. However in imaging each pixel has a corresponding spectrum. The instrument provides the chemical constituents present on the surface as well as bulk composition of a given material. Simple FTIR provides only preliminary information, but chemical imaging provides details about different constituents and their distribution.

Twin-screw Extruder: The instrument is being used for blending thermoplastic polymers and for compounding polymers with different fillers like nanoclay, short-glass fibres carbon black, etc. The merit of instrument lies in proper mixing of polymers, which leads to enhanced properties; precise control over various parameters like temperature, torque, and speed; and its ability of producing different extruded profiles. The facility is open for civil industry.

Dynamic Mechanical Analyser: The instrument is being used for extracting damping characteristics and transition temperature of rubber polymers, and mastic and composite materials. It has high force capability so that it can be used for testing wide variety of materials. It operates between very low temperature (-150 ^{o}C) to high temperature (500 ^{o}C), and low frequency of 0.001 Hz to high frequency of 200 Hz. The facility is open for civil industry.

Twin-bore Capillary Rhometer: The equipment is being used for rheological study of polymer blends, thermoplastic elastomer filled and plasticised polymer, etc. with shear rate higher than 10^5 and temperature range from RT to -450 ^{o}C. It is capable of measuring PVT, die swell, wall slip, and shear viscosity and rate with the help of Bagley and Rabiowitch corrections. The equipment has unique visual RHEO film software, which can provide curve fitting like Poner law and cross law polynomial. It can also give viscosity vs temperature curve (WLF, Arrhenious, etc.). The facility is open for civil industry.

Vector Network Analyser (45 MHz–26 GHz): This state-of-the-art analyser is used for microwave measurement to characterise the response of materials towards microwaves. It is a two part S-parameter measuring facility for measuring frequency from 45 MHz –26 GHz. The facility can also be used with rectangular wave guides measuring 2 GHz–18 GHz. The samples can also be measured under controlled temperature from QRT to 150 ^{o}C. The set-up can also measure complex permittivity (E'v and E"v) and magnetic permeability. The facility is open for civil industry.

Cold Chamber High-Pressure Die Casting Facility: One of the recent technologies emerging in the field of casting is semi-solid metal (SSM) processing for producing components of low porosity and fine uniform microstructure with high strength, improved dimensional accuracy and better surface finish. SSM processing incorporates elements of both casting and forging for the manufacture of critical and intricate shape parts to near-net shape finish. SSM components find application in automotive, aeronautical, and marine components of lightweight Al alloys. The copper-based SSM components are also used as underwater fittings. A cold chamber high-pressure die casting facility capable of handling SSM feed stock of aluminium and copper alloys has been established. The facility is capable of manufacturing thin and thick wall near-net complex shape components with high speed. It has pressure tightness capability of more than 5000 psi, and sound casting with excellent surface finish. The facility is open for civil industry.

Machine Capacity

Closing force	:	500 tons
Injection force	:	100 tons
Maximum weight of Al components	:	< 5 kg

Cold chamber high-pressure die casting machine

Editors are thankful to Dr J Narayana Das, Director, NMRL; Dr SC Sharma, Head and Dr C Durga Prasad, Dy Head, Technology Management Group for their help in bringing out this issue of *Technology Focus.*

VDukykth Qkdl d ikBd viu l>ko lkn] VDukykth Qkdl] MlhMkd] eVdkQ gkml] fnYyh-110 054 dk Hkt ldr gA
njHkkÔ: 011-23902475
QDl: 011-23813591
nk.kk&ey: technologyfocus@desidoc.deldom
b&ey: dirdesidoc@vsnl.net, dirdesidoc@drdo.org
bVjuV: http//www.drdo.org/pub/index.shtml

Readers of *Technology Focus* are invited to send their communications to the Editors, *Technology Focus* DESIDOC, Metcalfe House, Delhi-110 054. India
Telephone: 011-23902475
Fax: 011-23813591
Drona-mail: technologyfocus@desidoc.deldom
E-mail: dirdesidoc@vsnl.net; dirdesidoc@drdo.org
Internet: http//www.drdo.org/pub/index.shtml

Printed & published by Director, DESIDOC, on behalf of DRDO
MhvkjMhvk dh vkj l fun'kd] MlhMkd }kjk efnr ,o idkf'kr

RNI No. 55787/93