rainfed early sowing in NHZ; HD 3086 and DBW 88 for irrigated timely DBW 90 and WH 1124 for irrigated late and PBW 660 for rainfed sowing in NWPZ; NW 5054 and K 1006 for irrigated timely sowing in NEPZ; MACS 6478 for irrigated timely, HD 3090 for irrigated late and DBW 93 for restricted irrigation timely sowing in PZ; and HW 1098 (Dicoccum) for irrigated timely sowing in SHZ were identified. In barley, BHS 400 for rainfed early sowing in NHZ; DWRB 92 (malt) and BH 946 (feed) for irrigated timely sowing in NWPZ and HUB 113 for irrigated timely sowing in NEPZ were identified. These will be submitted to the CVRC for release as varieties for cultivation in India.

**Indu Sharma*, R. K. Sharma** and **R. Sendhil,** Directorate of Wheat Research, Karnal 132 001, India.
*e-mail: ispddwr@gmail.com

MEETING REPORT

# Nanotechnology-based innovation for environmental, energy and biomedical applications*

In the last five decades, a significant progress has been made in the field of advanced materials for diverse applications triggered by the advent of nanotechnology. The design of materials at nanoscale with significant property enhancement has been possible due to the development of novel fabrication techniques and characterization tools. These techniques together with evolving scientific thoughts have enabled newer applications of advanced materials in the cutting-edge technologies. For example, the spark plasma sintering (SPS), a variant of field-assisted sintering (FAST) or pulsed electric current sintering (PECS), has been widely used to fabricate bulk nanomaterials. The chemistry of the materials is refined and various coating techniques are being adopted to obtain nanostructured coatings. Newer characterization tools (e.g. SQUID, HRTEM, NMR, FIB) and high-performance computational tools are now extensively used to characterize/quantify as well as to predict the microstructure and functional properties of the designed materials at multiple length scales respectively. The last decade has also witnessed the application of nanotechnology based innovation to treat human diseases like cancer, osteoarthritis, osteoporosis, nerve repair, etc. Despite the projected advantages of nanotechnology, the application in various emerging fields as well as in the industry is still not commensurate with the research efforts in various laboratories and funding invested worldwide.

In lieu of the emerging trends, a five-day Indo-Japan bilateral symposium was organized to meet the following objectives: (a) to discuss the potential for future collaboration between Indian and Japanese researchers on green and life materials innovation based on nanotechnology; (b) to serve as a platform for a large number of active researchers from various disciplines of biological sciences, materials science, ceramics and biotechnology to participate and share their latest research results; (c) to strengthen existing collaborations between scientists in India and Japan; (d) to stimulate the minds of a large number of young researchers. Some of the themes of the symposium are schematically shown in Figure 1. The

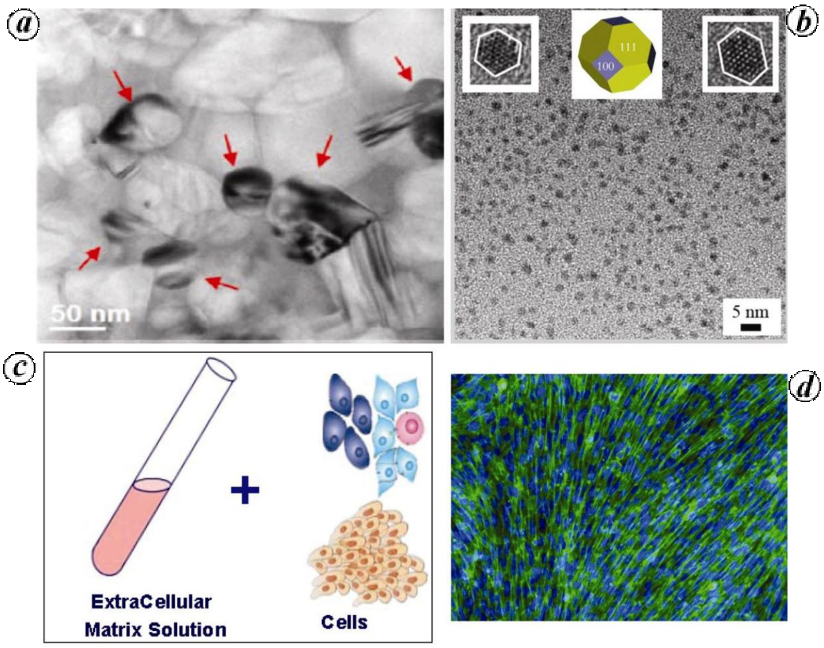


**Figure 1.** Illustration of the overall theme of discussion during the symposium. ***a***, Bright field TEM image of sintered $Si_3N_4$–SiC nanocomposite; ***b***, Bright field TEM image of gold nanoparticles with characteristic shapes as insets; ***c***, Concept of extracellular matrix-based scaffold synthesis; ***d***, Oriented myoblast (muscle cell) growth on electro-conductive hydroxyapatite (HA)–calcium titanate ($CaTiO_3$) substrate.

*A report on the Indo-Japan bilateral symposium 'Nanotechnology-based Innovation for Environmental, Energy and Biomedical Applications' held during 16–21 December 2013 at the Indian Institute of Science, Bangalore (http://mrc.iisc.ernet.in/~bikram/Bikram_Website/DST_JSPS_Symposium.html). This event was financially sponsored by DST, New Delhi and Japan Society for Promotion of Science.

participants deliberated on the ongoing research activities in this technologically important field of research and discussed the future of nanotechnology in the context of development of advanced materials. The symposium also intended to build a harmonious relationship for future collaboration between India and Japan on advanced materials.

In accordance with the theme of the symposium, the participants attended the lectures covering the length and breadth of the applications of nanomaterials in environmental, energy and biomedical fields. There were six technical sessions, each of which contained 4–5 lectures of 30 min duration and the symposium was spread over a period of 5 days. Among the 25 lectures, 9 of them were delivered by the Japanese delegates, most of whom were from Yokohoma National University and Tokyo University. A majority of the Indian counterparts were from IISc (Bangalore), IITs (Roorkee, Delhi and Bombay), Birla Institute of Technology, Pilani (Goa campus), CSIR laboratory (CGCRI, Kolkata) and DST laboratory (ARCI, Hyderabad) and a private company (Excel-Matrix Biological Devices Pvt Ltd, Hyderabad). During the symposium, a special visit was arranged to the National Nanofabrication Centre and Micro-Nano Characterization Facility at Centre for Nanoscience and Engineering, IISc. The opportunities for formal collaboration between India and Japan were discussed in terms of a number of funding avenues as well as areas of future collaboration.

In the case of nanomaterials for energy applications, Li-ion batteries and solid oxide fuel cells (SOFCs) form a major crux for efficient energy production. The talks on Li-ion batteries threw light on areas such as real-time stress measurements on thin film electrode materials during lithiation and delithiation, and formation of SEI passive layer over the electrode surface. All these methods are intended to tackle stress development during the lithiation–delithiation process by the incorporation of Sn–graphene composites into the electrodic system. To overcome the problems associated with cathodic materials in Li-ion batteries, economic alternatives such as alkali metal fluorosulphate ($LiFeSO_4F$) and alkali metal pyrophosphate ($Li_2FeP_2O_7$) were suggested for the next-generation Li-ion batteries. In the case of SOFCs, the design of novel Ni–YSZ anode material with enhanced electrochemical performance and a new family of solid oxide electrolytes, known as LAMOX series, with superior electrical conductivity were demonstrated. Some of the other topics deliberated upon were the characterization of superconducting thin films by scanning squid microscopy, computational predictability of thermoelectric power from thermoelectric materials and tuning the electronic properties of semiconducting bilayer transition metal dichalcogenides by applying normal stress. In one of the lectures, the fundamental aspects of the nucleation and growth of nanoparticles and nanohybrids were discussed. In the context of the application of ceramics for tribological and electronic applications, two lectures particularly focused on the development of nanostructured silicon nitride ceramics as well as the reaction-bonded silicon carbide as high-conductivity substrate materials.

In the area of nanotechnology application to the environment, the detection and removal of pollutants in the atmosphere at very low detection limits (ppb to ppt) are the major thrust areas. For the removal of aqueous pollutants, organosilanes linked to benzene dialdehydes and transition metal complexes grafted onto mesoporous silica were demonstrated to function by physical adsorption. Due to the superior thermal, mechanical and chemical stability of ceramics, filtration technologies are switching over to ceramic membranes as alumina and the fabrication of such membranes with controlled pore size of 0.6–1.2 μm for advanced filtration applications was elucidated. A novel electrochemical sensor for the sensing of ammonia at detection limits as low as 100 ppt using nitrogen doped carbon nanoparticles was illustrated.

Among the plethora of nanotechnology applications in the biomedical field, novel methods for highly cross-linked PVA hydrogels with superior mechanical properties, the use of functionalized carbon nanotubes and graphene in polycaprolactone composites for tissue engineering applications, somatostatin receptor-targeting nanoparticle-based radionuclide tumour detection, the monitoring of subsurface crack generation in steel and Ti alloys, and the computational design of coronary stents with superior mechanical properties were some of the highlights. A special emphasis was laid on the development of multifunctional biomaterials and the electric field modulation of cell functionality to achieve desired biological/tissue response and this was proposed as a paradigm shift from conventional tissue engineering approaches. The electrical characterization of fluorine-doped hydroxyapatite and the persistent polarization were revealed to promote osteoblast proliferation and differentiation, indicating the potential of polarized hydroxyapatite to enhance new bone formation. A special mention may be made on the use of $^{13}C$ solid-state NMR and transmission electron microscopy to monitor amyloid fibrillation. These are proteinaceous deposits found in tissues and organs as implicated in Alzheimer's and type-2 diabetes and human calcitonin was shown to play a major role in inhibiting amyloidoses. The presentation by the Hyderabad-based biomedical company proposed a new concept of the development of extracellular matrices and their integration with biological cells as 'snap of a finger' solution for wound healing and tissue regeneration. In order to overcome prosthetic infection, biocompatible silver-doped hydroxyapatite and titanium dioxide nanomaterials were demonstrated to exhibit excellent anti-biofilm activity at very low silver concentrations, without compromising on cytocompatibility.

In the concluding session of the symposium, Akira Naito (Yokohoma National University) and H. S. Maiti (former director, CGCRI, Kolkata) were felicitated for their outstanding contributions to science and technology.

**B. Sunilkumar** and **Bikramjit Basu***, Materials Research Centre, Indian Institute of Science, Bangalore 560 012, India; **Junichi Tatami** and **Atsushi Suzuki,** Yokohama National University, Japan.
*e-mail: bikram@mrc.iisc.ernet.in