# CHAPTER-2

# Industrial R&D Schemes

## III Patent Acquisition and Collaborative Research and Technology Development (PACE)

# PATENT ACQUISITION AND COLLABORATIVE RESEARCH AND TECHNOLOGY DEVELOPMENT (PACE)

## 1.0 PREAMBLE

The Department of Scientific and Industrial Research (DSIR) is continuing to operate the 12th Five Year Plan scheme on "Patent Acquisition and Collaborative Research and Technology Development (PACE)" during 2017-2020. The DSIR through the PACE scheme provides catalytic support to industries and institutions for development and demonstration of innovative product and process technologies, traversing the journey from proof of concept or laboratory stage to pilot stage, so that they can be launched for commercialization. The scheme supports ingenious work and assists in development of new technologies or creative/ innovative application of the existing technologies to solve unmet needs of industry. The scheme also strengthens the interface between industry, R&D establishments and academic institutions by supporting collaborative proposals. The scheme also jointly supports initiatives of other Ministries / Departments aimed at technology development and demonstration, e.g. IMPRINT initiative of Ministry of Human Resource Development/DST, wherein institutions of higher learning are being supported for development and demonstration of technologies.

Support is provided for proposals which give clear evidence of existence of proof-of-concept and aim at developing an innovative content for fulfilling an unmet need. Development and demonstration of technologies can be undertaken by industries alone (such as in-house R&D centres of the industry recognized by DSIR) or in collaboration with Universities, Public Funded Research Institutions or academic institutions. The technology development projects supported under the scheme aim at development of a new product or a process with attractive market potential which will result in significant benefits to the industry concerned in terms of raising its technological level, turnover, energy and material savings/recovery, export sales etc. Focus sectors include (i) Energy & Environment, (ii) Affordable healthcare including Drugs & Pharmaceuticals and Medical Equipment & Devices (iii) Agriculture, food & nutrition, (iv) Engineering (such as automobiles & auto-components, machine tools & foundry, automation & robotics, sensors etc.), (v) Specialty Chemicals etc.

## 2.0 OBJECTIVES

The objectives of the scheme are:

i. To support development and demonstration of indigenous product / process technologies, either by industry or by R&D organizations/ academic institutions / universities aimed at commercialization of new products and processes;

ii. To jointly support initiatives of other Ministries / Departments aimed at technology development and demonstration, e.g. IMPRINT initiative of Ministry of Human Resource Development and DST, wherein institutions of higher learning are being supported for development and demonstration of technologies.

iii. To support collaborative research between Indian Industry and R&D organizations/ academic institutions / universities for development and demonstration of lab scale technologies, aimed at commercialization of new products and processes;

## 3.0 TECHNOLOGY DEVELOPMENT AND DEMONSTRATION PROJECTS DURING 2018-19

### 3.1 New Projects

The Technology Development and Demonstration project proposals were invited from industries/ institutions against the seventh batch of advertisement and considered for recommendation by the Technical Advisory Committee (TAC) of the PACE scheme in its meeting held in October 2018. Following proposals were recommended for support.

#### 3.1.1 Development and standardization of manufacturing processes for large scale production of valuable secondary metabolites from callus-derived cells of vascular cambial explants of selected woody plant species - M/s Sami Labs Limited, Bangalore

M/s Sami Labs Limited, Bangalore has undertaken to develop and standardize the manufacturing processes for large scale production of valuable secondary metabolites from callus-derived cells of vascular cambial explants of six selected woody plant species and establish a 100 Lit suspension culture pilot plant facility. The company is currently manufacturing the targeted secondary metabolites by direct extraction methods and the current project proposes to upscale and optimize the procedure developed at lab level through a new route of continuous perfusion of in vitro cambial tissue cultivation for commercial production of secondary metabolites from cambial explants of six medicinal plants. The new technique is expected to lead to cost reduction, reduction in energy consumption /emissions and would have positive impact on environment by sparing the medicinal plants from destruction.

The project has been recommended for DSIR loan support of ₹ 150.00 lakh out of a total project cost of ₹ 329.65 lakh.

#### 3.1.2 Development & Optimization of Physical Vapour Deposition (PVD) TiCrAlN Coating Technology for Enhanced Energy Efficiency, Reduced Emission & Greener Mobility - Abilities India Pistons & Rings Ltd., Ghaziabad

M/s Abilities India Pistons & Rings Ltd., Ghaziabad in collaboration with their Israeli collaborators have undertaken to develop and demonstrate a specialized process based on the combination of Physical Vapour Deposition (PVD) and plasma-assisted process using triple vacuum arc magnetically supported PVD technology for TiCrAlN coating on piston rings for 2/3 wheel engines. The objective of the project is to achieve higher performance standards in the automotive or two-wheeler vehicles (motorbikes, scooters) & lawn & garden machinery with specialized surface engineering technologies and coating technology and to improve the various physical, mechanical, tribological and thermal properties of piston rings that can lead the improvement in the energy performance and reduction in the emissions of the engine.

The project has been recommended for DSIR loan support of ₹ 400.00 lakh out of a total project cost of ₹ 1296.00 lakh.

#### 3.1.3 Next Generation Data Processor Unit (NGDPU)- Rajasthan Electronics & Instruments Limited, Jaipur

M/s Rajasthan Electronics & Instruments Limited, Jaipur manufactures Data Processor Milk Collection Unit (DPMCU), a dedicated unit which receives, processes and transmits data and is used by various milk collection agencies in the dairy sector as one of its product line. The company is looking at new requirement for a scalable and modular product and has undertaken to develop and commercialize Next Generation Data Processor Unit (NGDPU) with a dedicated Single Board Computer based solution with customized hardware & software design having all smart and advanced features at a cost that is lower in comparison to their existing and prospective

customers. The NGDPU will have a number of smart features and functionality of performing transaction viz. instant data upload on centralized server, instant calculation for payment etc.

The project has been recommended for DSIR loan support of ₹ 40.00 lakh out of total project cost of ₹ 117.00 lakh.

## 3.2 On-Going and Completed Projects

### 3.2.1. Development of Controller Release [CR] Formulation of Natural Highly-Purified Human Chorionic Gonadotropin [hCG] – M/s Sanzyme Ltd. Hyderabad & ICT Mumbai

M/s Sanzyme Ltd., Hyderabad in collaboration with Department of Pharmaceutical Sciences & Tech., Institute of Chemical Technology, Mumbai had undertaken a project on "Development of Controlled Release [CR] Formulation of Natural Highly - Purified Human Chorionic Gonadotropin [hCG] under PACE-TDD scheme. 99% pure hCG is used as a surrogate for LH [Lutenising Hormone] for triggering ovulation and maintenance of pregnancy. However recent developments, have shown that the role of hCG is not restricted to infertility treatment alone but has wider applications in the field of metabolic disorders such as Diabetes and other clinical conditions where hCG is being used for a process known as angiogenesis in the fields of vascular surgery and CNS surgery. Currently two forms or variants of hCG are available, either as highly purified form or the recombinant version of hCG. Despite recombinant version being available, only a single dosage form is available for clinical use. The project aims to improve compliance and reduce the frequency of injections and make the treatment more affordable and available to masses rather than to people of a certain class alone. The CR- release formulation using nano technology with release rates of either 15 or 30 days will reduce the frequency of injections required in infertility problems, maintenance of pregnancy and controlling metabolic disorders such as Diabetes.

An HPLC method has been developed and validated for the determination of drug content for encapsulation of hCG in the formulation, for in-vitro drug release studies and stability studies. SDS-PAGE was developed for qualitative determination of hCG in formulation during processing and stability studies. The microspheres formulation was prepared by double emulsion solvent evaporation method, wherein the optimization of speed of In-line homogenizer was important for desired particle size of microspheres. The speed was optimized by taking placebo batches at different rpm of In-line homogenizer. The release profile of hCG was optimized using the different grades of PLGA polymer, in which Resomer RG 503H grades polymer showed desired in-vitro release profile pattern for a period of 15 days

Stability studies were carried out under the project. The Gel Electrophoresis was performed using a Bio-Rad Mini-Protean II electrophoresis system (Hercules, CA) to investigate the stability of hCG during fabrication of microspheres. Thus, considering the stability of hCG as protein, initially 3000 rpm vs fixed as the optimal dispersion speed for the formation of secondary double emulsion. The SDS-PAGE of hCG samples and hCG microspheres were performed. The bands were obtained for the samples, viz, hCG standard in water, hCG standard in Acetonitrile and water mixture, hCG extracted from hCG microspheres batch 503 B-31 and 33 batch respectively which showed the single band. This indicates no degradation of the protein. Hence, it was concluded that the hCG was stable to all the process environment and parameters.

The stability of hCG in the microspheres formulation was evaluated by bioassay method at M/s SanzymePvt Ltd. In-vitro label claim of hCG in microspheres was found to be 812 IU/mg by HPLC analysis. However, from the in-vivo bio assay, it was found to be 388.78 IU/mg. The bioassay study of HCG PLGA formulation in the animal model showed the bioactive nature of hCG. Based on the in-vitro release study and pharmacokinetics of hCG PLGA microspheres formulation at different doses of hCG were studied. This study revealed that, in-vivo hCG serum level from the microspheres formulation is much higher than the marketed formulation from the 3 days to 13 days in the animal model at a 5000 IU dose strength.

The project has been supported by DSIR with a soft loan of ₹ 52.50 Lakhs to M/s. Sanzyme Ltd., Hyderabad and a grant of ₹ 52.24 lakhs to ICT, Mumbai out of a total project cost of ₹ 159.55 Lakhs in December, 2016. The Project is under progress.

### 3.2.2 MacroalgalBiorefinery for $CO_2$ Sequestration and Production of Biofuel and Value-Added Compounds – M/s AquAgri Processing Pvt. Ltd., New Delhi & DBT-ICT Centre for Energy Biosciences & CSIR-CSMCRI, Bhavnagar

M/s AquAgri Processing Pvt. Ltd., New Delhi in collaboration with DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology(ICT), Mumbai and CSIR- Central Salt & Marine Chemicals Research Institute, Bhavnagar (CSIR-CSMCRI) have undertaken to demonstrate the concept of sequestration of $CO_2$ through large scale controlled growth of macroalgal species (Ulva) in closed photo-bioreactors using $CO_2$ generated by power plants or other industries, and making the technology sustainable through conversion of the grown macroalgal biomass tobioenergy and other value-added products. Globallythe dry sea plants are used to manufacturehydrocolloids and these have a wide application infood, cosmetics and toiletry industry. Aqua Sap derived from the fresh living algal plants is a plant nutrient, which contains substantial amounts of micro and macronutrients, naturally occurring Plant Growth Regulators (PGRs) and amino acids. The PGRs such as Auxins, Cytokinins and Gibberellins, accelerate the metabolic function of the plant there by boosting yield and productivity. The concept of a multi-product macroalgal refinery using modular photo-bioreactors for $CO_2$ capture and growth of Ulva in vertical glass reactors to demonstrate efficient $CO_2$ sequestration coupled with downstream processing technologies for biomass deconstruction and separation of value-added products for economic sustainability is an innovative concept.

Fig. 1 Ulva Biomass harvested from 1KL Airlift tubular photobioreactor at DBT-ICT Centre for Energy Biosciences

ICT and CSIR-CSMCRI has developed and demonstrated Ulva cultivation in flat panel and tubular photo-bioreactors (PBRs) made using glass, flexible HDPE and polycarbonate material with various designs. A polycarbonate tubular bio-reactor system has been finally created and is successfully run at ICT for about a year and the entire plant performance data has been validated. The bio-reactor system is giving excellent biomass productivity (0.33 g DW/L/d i.e. dry biomass weight per Liter per day); (> 30 % daily growth rate (DGR) and thus higher rate of $CO_2$ sequestration which is better than targeted. The economics of the airlift tubular photo-bioreactor system needs further engineering improvisation and cost optimizations for reduction of capex cost for scaled up demonstrator and commercialization. For this a 1KL system is being erected for improvisation at Aquagri before it is scaled up 100 KL plant. A tractable integrated process facilitating sequential extraction of the major value added components such as sap, lipids, protein ulvan and cellulose has been achieved and a10KL extraction unit for downstream processing of Ulva biomass has beencommissioned at M/s Aquagri project site.

The project has been declared technically completed with a recommendation that future scale up activity in field would be completed by M/s AquAgri Processing Pvt. Ltd., New Delhi on its own. The project has been supported by DSIR with a soft loan of ₹ 25.00 Lakhs to M/s AquAgri Processing Pvt. Ltd., New Delhi and grants of ₹ 60.00 Lakhs to ICT and ₹ 30.00 Lakhs to CSIR-CSMCRI.

### 3.2.3 List of other PACE TDDP projects which were completedor withdrawn are as below:

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|---|---|---|
| 1 | Technology up gradation of pelletization facility for herbal veterinary feed supplements: Demonstration in terms of value addition to produce quality supplements at low cost – M/s Natural Remedies Pvt. Ltd., Bangalore | Completed |
| 2 | Development of Genetically Engineered Cellulose-free Alkaline Xylanase through submerged fermentation process (SMF) – M/s Kaypeeyes Biotech Pvt. Ltd., Mysore | Completed |
| 3 | Design, Manufacturing, Proving, Supply of Three Roller Flow Forming Machine - M/s ParasFlowform Engineering Ltd., Mumbai | Completed |
| 4 | Chitosan Based Drug Delivery system for Dental and Oral Diseases - M/s ICPA Health Products Ltd., Ankleshwar& Govt. College of Pharmacy, Aurangabad | Withdrawn by company |
| 5 | Cold plasma based technology development for green ammonia/urea production – M/s Nagarjuna Fertilizers and Chemicals Limited, Hyderabad | Withdrawn by company |
| 6 | Cost –effective 3G/4G based Multimedia Video Conferencing service-Intellisys Technologies & Research Ltd. Kolkata | Withdrawn by company |

## 4. 0 TECHNOLOGY DEVELOPMENT PROJECTS UNDER IMPRINT INITIATIVE

IMPacting Research INnovation and Technology (IMPRINT), the first-of-its-kind Pan-IIT and IISc joint initiative, is a Ministry of Human Resource Development (MHRD) and DST initiative to address major engineering challenges that the country must address and champion to enable, empower and embolden the nation for inclusive growth and self-reliance. Department of Scientific and Industrial Research has partnered with MHRD in implementing this program. In order to pursue the mandates of IMPRINT, ten technology domains as grand engineering challenges have been thought of. DSIR is contributing in two sectors, viz, Manufacturing Technology and Water Resources. Five IMPRINT proposals of IITs/IISc/NITs in the two identified sectors for DSIR (Manufacturing Technologies and Water Resources) have been supported. DSIR grant support is matched by MHRD. The details of IMPRINT projects supported under PACE scheme are as follows:

### 4.1 Development of an innovative process to fabricate ultra-fine grained bimetallic thin sheets for microforming applications - IIT Madras

The project aims to develop micro deep drawn components made up of bimetals with ultrafine grained microstructure. Such micro-components have potential application in many industries such as consumer electronics, telecommunication, micro electro-mechanical system (MEMS), aerospace and defence. For this purpose, a novel approach involving combination of cryorolling (CR), warm roll bonding (RB) and asymmetric rolling (AR) have been proposed, aimed to fabricate thin bimetallic sheet, with equiaxed ultra-fine grained (UFG) microstructure. Possible advantages of using such material in microforming are: (i) Improved microformability by engineering desirable texture (ii) Overcoming challenges associated with size effect as observed during micro-manufacturing (iii) Strong interfacial bonding at bimetallic interface (iv) Excellent mechanical strength due to presence of UFG microstructure. There are two major novel ideas involved in this proposal:

(i) Although all the three rolling processes (CR, RB, AR) has been extensively studied in a standalone basis, its only recently, researchers are trying to combine various process to tailor required properties in sheet metals. In the present work, a novel combination of CR+ warm RB + AR is proposed for the first time to develop UFG bimetallic thin sheets. The thin UFG bimetallic sheets developed by this innovative method are expected to provide favourable texture for microforming, high bond strength between bimetallic interface and improved microformability.

(ii) Microforming itself is a less explored domain. Although some progress has been made to microform metals and alloy, no attempt has been made by any

researchers to obtain bimetallic micro-components of ultrafine grained microstructure using microforming process.

Bhabha Atomic Research Centre is a potential end user of the bimetallic micro components made by the proposed method. The Centre for Design and Manufacture, BARC has highlighted that product developed by this technology will find many purposeful applications in the Centre.

Under the project, a custom designed Asymmetric Rolling and Roll bonding setup for fabricating bimetallic UFG sheets has been successfully designed and developed. This custom designed setup was fabricated at M/s Newfield Pvt. Ltd., Bangalore and installed at IIT Madras. Ultrafine grained sheets of Al and Cu were successfully developed via cryorolling. A significant strength enhancement (3 times increment) was found in ultrafine grained Al and Cu sheets as compared to their base counterpart. Detailed thermal stability study of ultrafine grained Al and Cu sheets and FEM simulation and process simulation for roll bonding of ultrafine grained Al-Cu sheets was successfully carried out and optimum processing parameters prior were obtained. Activities of evaluation of micro-formability of the developed bimetallic sheets at different domain, correlating the effect of grain size and texture with the microformability and development of a micro/ mesoscopic model for prediction of microformability are under progress.

The project has been supported by DSIR with a grant of ₹ 83.46 Lakhs out of a total project cost of ₹ 166.92 Lakhs. The Project is under progress.

## 4.2 Fabrication and evaluation of atomic force microscope probes with detachable and re-usable tips - Indian Institute of Science, Bangalore

The broad applications of atomic force microscope (AFM), from in-line nanometrology and imaging to nano-manipulation, are ultimately tied to the AFM probe. The AFM probe is a consumable part requiring frequent replacement, and its high cost contributes significantly to the running costs of AFM. The probe needs replacement when its tip is damaged even if the rest of it is functional. Here we propose batch fabrication of AFM probes wherein the probe-tip alone is replaced. Since several thousand tips can be fabricated in the same area as a conventional probe, this approach is highly cost-effective and facilitates development of advanced probing systems. The main objectives of the project are i) tip-less AFM cantilevers and detachable AFM tips are fabricated; ii) an AFM cantilever carrying a detachable tip is evaluated by imaging nanomaterials in different modalities and iii) automated detection of tip-wear, tip-replacement and re-use would be demonstrated.

To ensure quality control during nano-fabrication, it is essential to employ in-situ inline inspection and metrology tools. The AFM is the primary tool suited for this requirement since, unlike competing techniques such as the SEM and TEM, the AFM can operate in-situ with sub-nanometer precision and interact with a range of samples. However, every AFM requires frequent replacement of its tip, and the existing replacement techniques suffer from limitations ranging from imprecision, excessive time consumption to high cost that together act as major impediment for industrial use of AFM. The proposed replaceable tips address these issues and possess the following advantages:

i The cost of replacement a single tip is reduced significantly. The probe is not replaced, and hence its properties need not be recalibrated.

ii Automated in-line inspection with reduced replacement time and increased precision can be achieved

iii Enables employing more sophisticated probes, with integrated sensing and actuation to achieve controlled interaction with 3D nano-scale samples.

Under the project, AFM cantilevers without tips and AFM tip using dry-etching techniques has been batch-fabricated. A wax-based micro-grippers and automation of tip pick-up and drop-off has also been successfully developed. Activities of fabrication of AFM probes with tips, detachable AFM tips and automated detection of tip-blunting and execution of tip replacement are under progress.

The project has been supported by DSIR with a grant of ₹ 18.075 Lakhs out of a total project cost of ₹ 36.15 Lakhs. The Project is under progress.

### 4.3 Low-cost Additive Manufacturing Technique for Fabricating Through - Substrate Vias based Three-dimensional Microstructures used in MEMS Applications – IIT Bombay

A low-cost additive manufacturing technique is proposed to fabricate 3D microstructures required in MEMS applications, such as inductors. In the proposed 3D microstructures, top structures will be connected to the bottom structures by vertical metal-filled vias known as through-substrate vias (TSV). A low-cost electrochemical-discharge machining (ECDM) will be used to create holes in borosilicate-glass and silicon substrates. Conductive metals such as copper, nickel, etc., will be deposited in these holes by a novel void-free, "aspect-ratio-dependent electrodeposition technique. To form top-side and bottom-side coils, layer-by-layer polymer lamination and electrodeposition will be used. Wettability study of polymer mold with the electrolyte will be performed. Electrical characterization and reliability analysis of metal-filled TSV will be carried out. The TSV-based 3D inductors made by the proposed method will incur lower fabrication cost, shorter electrical interconnect path, faster signal speed and reduced foot-print area as compared to conventional inductors.

Under the project, an in house electrochemical discharge machining (ECDM) setup for non-conductive materials has been developed and fabricated. Optimization of ECDM parameter viz. machining voltage, electrolyte concentration, pulse frequency and duty cycle has been completed and experiments have been performed in glass samples to evaluate individual parameters effect on the quality of hole formation. Fabrication of single as well as multiple tool electrodes has also been achieved. Activities of conductive seed layer deposition, via filling by electro-deposition, hydrogen gas bubble entrapments etc. are under progress.

The project has been supported by DSIR with a grant of ₹ 72.69 Lakhs out of a total project cost of ₹ 145.38 Lakhs. The Project is under progress.

### 4.4 Designing and fabrication of an aerodynamic lens for nanoparticles of variable size – IIT Hyderabad

The main objective of the project is to design and fabricate an instrument (aerodynamic lens) to tightly collimate beams of nano/microparticles and fabricate a high resolution mass and imaging spectrometer for real-time analysis of the chemical composition of aerosols with designed mass resolutions of m/Δm of ~ 700, upto a mass of 800 amu., with fast response rates upto 10 Hz or better. The project also aims to develop a large through put method to fabricate microstructures with resolutions of better than 0.5 mm using the aerodynamic lens system. The robust and compact instrument will be designed for deployment on mobile systems, terrestrial and airborne. The industry partner for the project is H. Fillunger and Co. Pvt. Ltd., having extensive experience in vacuum systems, plasma deposition systems etc. and will collaborate in the fabrication of the lens system. The project also proposes to develop a methodology for deposition of thin and uniform layers on surfaces for additive fabrication of microstructures using the lens system.

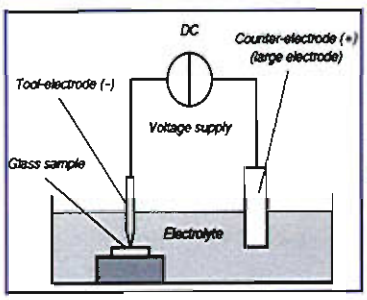


Fig. 2 Schematic for fabricating TSV.

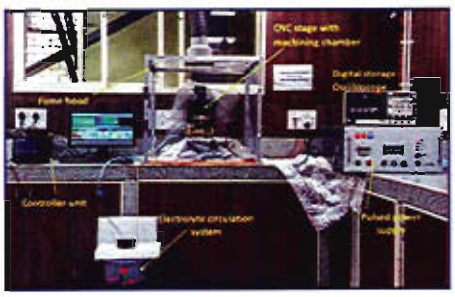

Fig. 3 ECDM Experimental setup

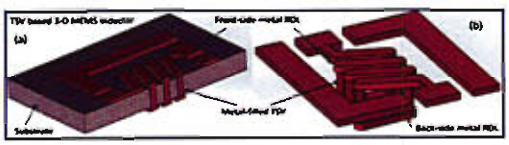

Fig. 4 TVS based 3-D MEMS Inductor

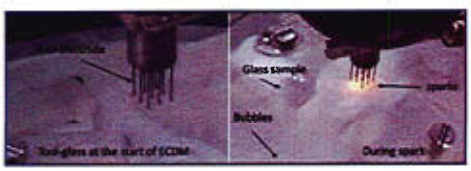


Fig. 5 Tool array with multiple tool tip on pre-designed locations

Under the project, design and fabrication of a low cost, compact, high resolution mass spectrometer is carried out for the first time in India. The assembly of the spectrometer has been completed. First stage of the aerodynamic lens has been tested and more lenses are being added and testing is under progress. The electronic system of the Spectrometer is under testing and the characterization of the Spectrometer would be under taken after integration of the electronics. M/s Fourvac Technologies is participating in fabrication of the spectrometer and a MoU has been signed with M/s Gray Scientific Laboratories (GSL) for commercialization.

The project has been supported by DSIR with a grant of ₹ 25.60 Lakhs out of a total project cost of ₹ 51.20 Lakhs. The Project is under progress.

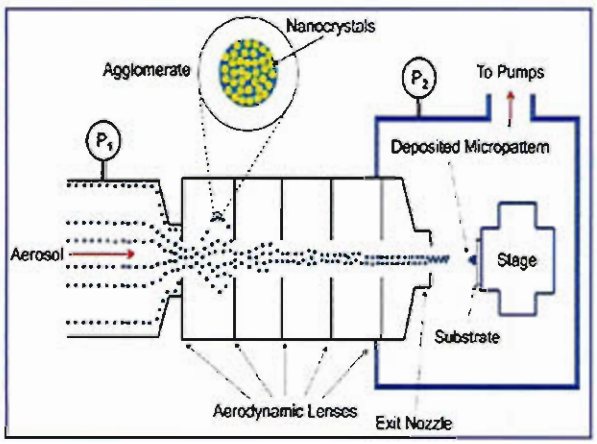


Fig. 6 Schematic of the proposed particle deposition system

Fig. 7 Aerodynamic lens with multiple and variable size orifices

## 4.5 Continuous discharge measurement in small open channels by using ultrasonic tomography – IIT Kanpur

The project aims to develop a continuous real-time discharge monitoring system for small open channels (width 1 to 50 m) by tomographic reconstruction of ultrasonic transit-time measurements. The system will be designed to be accurate, cost-effective, field deployable, easy to calibrate and capable of unattended real-time data transmission. The developed system will be tested under laboratory and field conditions and determine its range of measurement errors under different channel geometry and flow conditions. The developed system will be a user-friendly commercial product.

Small rivers and channels dominate Indian rural and urban landscape. Monitoring discharge in them has direct utility in managing water-resource distribution issues prevalent in India today. The infrastructure for discharge data collection in small rivers is either absent or greatly limited by manual methods that use current-meters, floats, and gauges. The continuous discharge monitoring instruments that are readily available in the market like Acoustic Doppler Current Profiler (ADCP) and Laser Doppler Anemometer (LDA) are too expensive for multiple deployments. The motivation is to fill this gap by developing a discharge measurement system that is inexpensive, easy to deploy, operate and maintain, and requires minimum calibration. The scope of this project is to develop and test an ultrasonic transit-time discharge measurement system for small channels (width 1 to 50 m). The configuration of the ultrasonic transducers will be designed to get a cost effective flowmeter with measurement error of less than 5%.

Under the project, an automated calibration setup for high (up to 40 lps) and low (up to 0.55 lps) flows have been designed and successfully fabricated. Ultrasonic transducers for developing flowmeters have been identified and tested with commercially available and in-house designed electronic circuitry. An in-house inline ultrasonic flowmeters (UFM) for pipes has been developed and the first ultrasonic transit time open channel flowmeter using the selected pair of transducers and circuit boards has

been assembled. Extensive laboratory and field experiments for calibrating and testing developed open-channel flowmeters and tomographic reconstructions for improving reliability and accuracy of ultrasonic transit-time flow measurements are under progress. M/s Kritsnam Technologies Pvt. Ltd. is associated for designing/improving circuitry associated with transducers for flowmeters, power consumption reduction and designing a rugged casing for the flowmeter and integrating it with wireless technology

The project has been supported by DSIR with a grant of ₹ 57.84 Lakhs out of a total project cost of ₹ 115.68 Lakhs. The Project is under progress.


Fig. 8 (a)

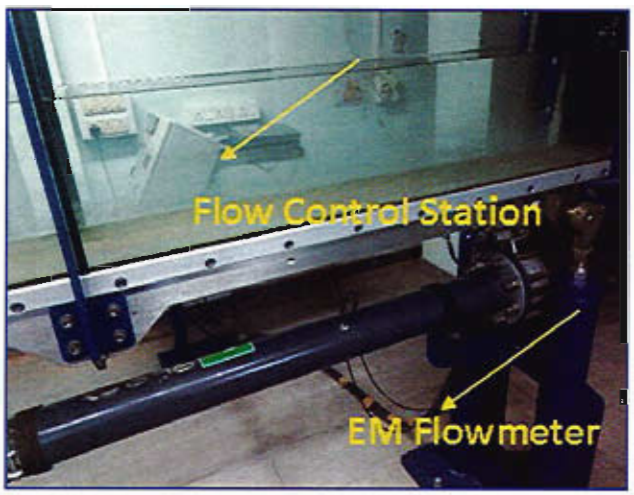


Fig. 8 (b)

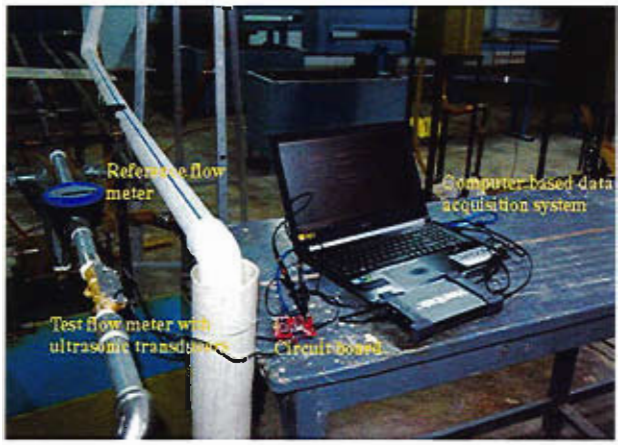


Fig. 8 (c)

Fig. 8 Laboratory set-up for Ultrasonic transit-time flowmeter for open channels