FP7-Energy-2010-India Call

Advanced Grating for Thin Film Solar Cells (AGATHA) : Highlights

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Overview

- EP7-Energy-2010-India Call: our success journey
  - Project Highlights
  - About Partners
  - FP7 Proposal development
  - Reviewers Comments
- AGATHA Concepts and Innovation
- Details on CSIR-CMERI involvement
- Operational capabilities:
  - Micro-Nano systems engineering systems research in CSIR-CMERI

Project Highlights and Promises

- Project category: EU-India Coordinated Call
  - Development of novel materials, device structures and fabrication methods suitable for thin film solar cells and TCOs.
- Duration: 36 months (Jan 2012 –Jan 2015)
- Promises:
  - The optical design to increase solar cell's light trapping capability:
    - Total internal reflection by modulated surface textures
    - Micro-texturing of glass by hot embossing
    - Nano-texturing of the top TCO layer by etching
    - Increasing short-circuit current and EQE
    - New texturing process chain suitable for high production throughput
  - Implementation on a-Si:H, µ-c-Si:H and CIGS based thin films technologies: Active material thickness reduction
    - A-Si:H = 250nm to 150nm
    - µ-c-Si:H = 1.5µm to 1µm
    - CIGS = 2.5µm to 800nm
  - Increase in short-circuit current = 15%

EU-INDIA Partners

- **Dr. Dipayan Sanyal**
  Sr. Principal Scientist, Central Glass and Ceramic Research Institute, Kolkata
- **Dr. Nagahanumaiah**
  Sr. Principal Scientist Central Mechanical Engineering Research Institute, Durgapur
- **Prof. Sundarranjan Asokan**
  Department of Instrumentation, Indian Institute of Science, Bangalore
- **Dr. Rathindra Nath Das**
  Additional General Manager, Bharat Heavy Electricals Limited, Bangalore
- **Mr. Ranganath S. Ekkundi**
  Group Director, Power Systems Group, Indian Space Research Organisation, ISRO Satellite Centre (ISAC), Bangalore
- **Dr. Etienne Quesnel / Dr. Pierre Juliet**
  Senior Programme Manager, Commissariat à l'énergie atomique / CEA/LITEN, France
- **Prof. Miro Zeman,**
  Professor and Head, Photovoltaic Materials and Devices Laboratory, Delft University of Technology / TUD, Netherlands
- **Dr. Salvatore Coffa,**
  Head, IMS R&D, S T Microelectronics Italy
- **Dr. Tsvetelina Merdzhanova and Dr. Olesksandr Astakhov,**
  Research Staff, Forschungzentrum Jülich, Germany
- **Dr. Alistair Kean,**
  Technical Director, Mantis Deposition Ltd. UK

How did we form the consortium?

- Dr. Nagahanumaiah and Prof. Ashokan working together for sometime
- Dr. Sanyal and Dr. Nagahanumaiah are working together
- Dr. D. Sanyal and Dr. RN Das worked together earlier
- Dr. RN Das and Dr. RS Ekkundi working together (BHEL-ISRO)
- Similar working relation does exists between EU partners
- EU-India collaborations established through referrals
  - Dr. D. Sanyal works with other French researcher in their other EU-India project
  - Dr. Nagahanumaiah have collaborations with other French researchers

FP7 Proposal Format

- PART –A
  - The project summary
  - The list of beneficiaries
  - Work plan tables – detailed implementation
    - List of work packages
    - List of deliverables
    - Work package descriptions
    - List of Milestones
    - Tentative schedule of project reviews
    - Project efforts (in person months) by beneficiary per work packages
    - Project efforts by activity type per beneficiary

FP7 Proposal Format

- Part – B
  - Scientific and/or technical quality, relevant to the topics addressed by the call
    - Concept and objectives
    - Progress beyond the stat-of-the-art
    - S/T methodology and associated work plan
    - Overal strategy of the work plan
    - Timing of the different WPs and their components Gantt chart
    - Detailed work description broken down into work packages
    - Graphical presentation of the components showing their interdependencies
    - Describe any significant risks, and associated contingency plans
  - Implementation
    - Management structure and procedures
    - Individual participants
    - Consortium as a whole
    - Resources to be committed
  - Impact
    - Expected impacts listed in the work programme
    - Dissemination and/or exploitation of project results, and management of intellectual property
  - Ethical Issues
  - Gender aspects in the consortium

Description of Work Packages

- Organization of work packages
  - Division of project to work packages
  - Brief theme of the work packages
  - Description of work packages

Work Package No.	WP - I			**Start - End Dates**				Month 1 to 36		
Work Package Title										
Activity Type										
Participants	CM1	CM2	CM3	CM4	CM5	CM6	CG1	NA1	IM1	
Number of Scientists	03	02	04	03	02	02	02	01	03	
Objectives: 1. _____ 2. _____										
Description of work : 1. Task 1.1: _____ 2. Task 1.2: _____ *Deliverables:* -										

Description of Research Tasks/Activity

Research Task No.	T 1.1			**Start - End Dates**			Month 1 to 36			
Task Title										
Activity Type										
Activitity Leaders (s)										
Participating Scientists /TO (initials may be used)										
Objectives: 1._____ 2._____										
Description of Task/Activity : *Deliverables:* -										

Coordination Agreement

- Coordination agreement is based on
  - EC regulations No. 1906/2006…
  - Agreement for scientific and technological cooperation between the European Community and the Govt. of Republic of India of 23 Nov. 2001
  - Between all the beneficiaries (partners)
- Section 1: Definitions (party, consortium…)
- Section 2: Purpose: coordination agreement
- Section 3: Entry into force, duration and termination
- Section 4: Responsibilities of parties: breach, third party involvement
- Section 5: Liability towards each other
- Section 6: Governance structure: Coordinators, general assembly and work package leaders
- Section 7: Financial provisions
- Section 8: Foreground: ownership
- Section 9: Access rights
- Section 10: Non-disclosure of information
- Section 11:Miscellaneous

Evaluation Criterion

- Importance
  - Relevant because it addresses, fully or partially a topic that is open in the call and it corresponds to an eligible funding
  - If YES. The consensus scores and comments
  - If NO. This proposal is out of scope because…
- Scoring = (0 – 5) half mark is allowed
  - 0 = Proposal fails address or can not be judged due to missing information
  - 1 = Poor: There is serious inherent weakness/criterion is poorly addressed
  - 2 = Fair: While proposal addresses the criteria well, there is a significant weakness
  - 3 = Good: The proposal addresses the criterion well, although improvements would be necessary
  - 4 = Very Good: The proposal addresses the criterion very well, although certain improvements still possible
  - 5 = Excellent: The Proposal successfully addresses all relevant aspects of the criterion in question
- Total score
- Any other remarks
- Does the proposal raises ethical issues

Evaluation Summary Review

- Quality and efficiency of the implementation and the management : **Score = 4.00**
  - Professional management structure and procedures are well described.
  - The experience and quality of all participants is well documented; each is a specialist in their own fields.
  - The consortium as a whole is complementary and well balanced, but Indian experience in thin film technology should have been better represented.
  - Person months on the EU side are very high given the narrow focus of the work represented.
  - The cooperation of Indian and European partners is a fundamental part of the project and is very well provided for in the proposal.

Evaluation Summary Review

- Potential impact through the development , dissemination and use of project results : **Score = 3.50**
  - The impact on efficiency is moderate and consistent with the requirements of the call
  - There is no indication in the proosal of the expected stability of the devices as a whole over their lifetime.
  - A good dissemination structure is proposed
  - The exchange of the researchers and mutual teaching opportunities (summer schools) as proposed will significantly contribute to enhance cooperation between industry and academia in the EU and India
- Recommended for negotiation (scores were above threshold)

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Process of Negotiation

- European Commission
- Negotiation Mandate is issued
  - Updated description of work inline with the reviewers comments
  - Funded 1789584 Euro for 36months
  - Coordination Agreement signed by all EU-India partners has been submitted to EU

- DST, Govt. of India
- Conducted a special meeting with the leading domain experts for the projects eligible for a grant negotiation
  - DST suggested to prepare a India specific supplementary document
  - Expert committee recommended to retain all three India-EU projects, which were eligible for the grant negotiation (ESCORTS, AGATHA and OISC-LARGECELL)
  - Coordination Agreement signed by all EU-India partners has been submitted to DST

Project Highlights and Promises

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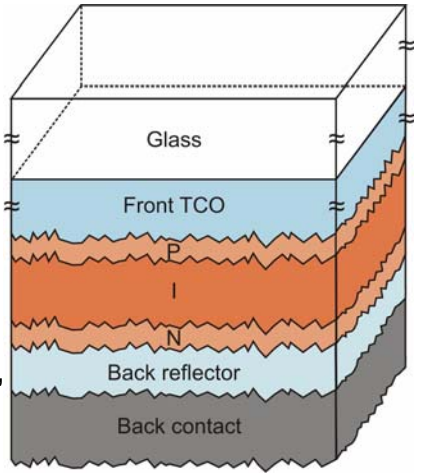
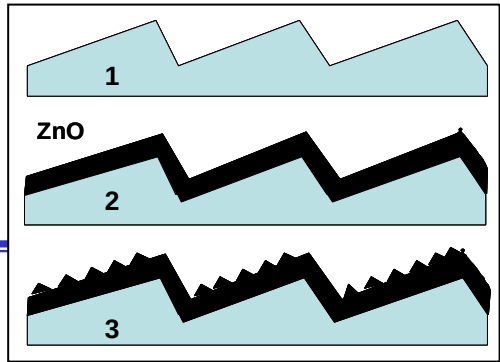
AGATHA Concepts and Innovation

- Single Crystal silicon solar cells
  - Solar cells based on single-crystal silicon or epitaxial compound semiconductors provide the highest conversion efficiency.
  - Single-crystal solar cells and associated concentrator cells are still higher in cost than desired for generalized commercial use.
- Thin film solar cells
  - Polycrytalline or amorphous thin film solar cells provide a lower cost alternative to bulk and epitaxial single-crystalline solar cells.
  - Several thin-film based solar cells do exist, including copper indium gallium diselenide Cu(In,Ga)Se2 (CIGS), Cadmium Telluride CdTe, organic materials, amorphous silicon, microcrystalline silicon, and thin-film silicon alloys.

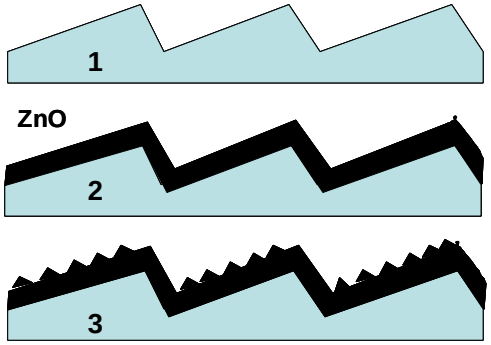


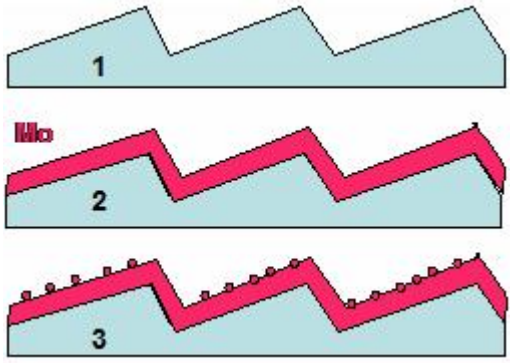
- Issues associated with thin film solar cells
  - The minority carrier diffusion lengths are generally small in these polycrystalline or amorphous thin films.
  - Requiring thin layers to maximize charge collection efficiency.
  - Requirement for thin layers is contradictory to the requirement of maximizing solar energy absorption.
  - Optical absorption in thin films is particularly small at longer wavelengths near the band edge of the thin-film material, where the absorption coefficient is low.
- **AGATHA aims at developing a low cost process chain to incorporate advanced light trapping scheme based on 'Modulated surface textures" in Si based and CIGS thin film solar cells**

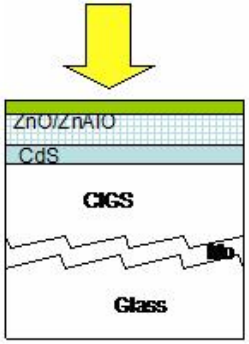


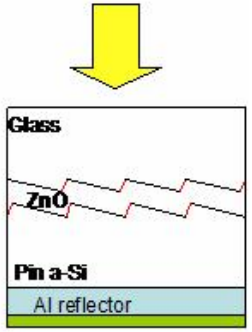
AGATHA Concepts

- **Si based cells**
  - Hot Embossing of an asymmetrical periodic grating in the front glass to achieve long-range texture
    - Period ~ 1µm; height = x 100nm
  - Deposition of conformal TCO layer on the periodically structured glass
  - Achieving the texture modulation by TCO nano-textures (50-300nm wide features) by chemical etching to achieve the short range texture
- **CIGS Cells**
  - Hot embossing of an asymmetrical periodic Grating (period ~1µm, height a few 100 nm) in the back face glass to achieve the long range texture.
  - Deposition of conformal Molybdenum layer on the periodically structured glass.
  - Achieving the texture modulation by Molybdenum Nano-texturation (100-300 nm wide features) by Mo Nano-particles to achieve the short range texture.

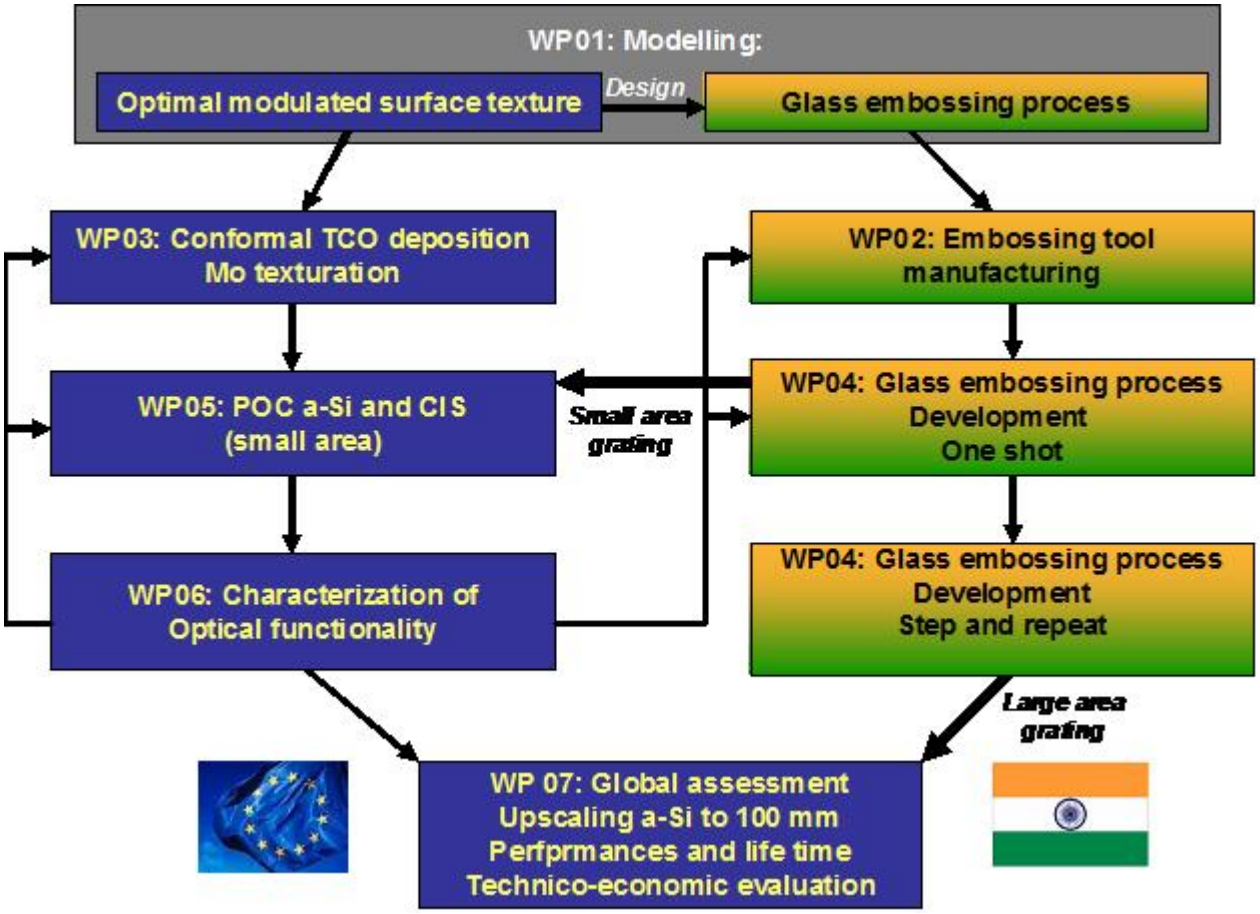








Work Packages



- WP1: TUD + CEA
- WP2: CSIR-CMERI
- WP3: MD
- WP4: CSIR-CGCRI
- WP5: TUD + BHEL
- WP6: IISC +JUELICH
- WP7: ST
- WP8: CEA + CGCRI (Project management)
- WP9: ST + CGCRI (Dissemination)
- WP10: CEA + CGCRI (Tech. Coordination)

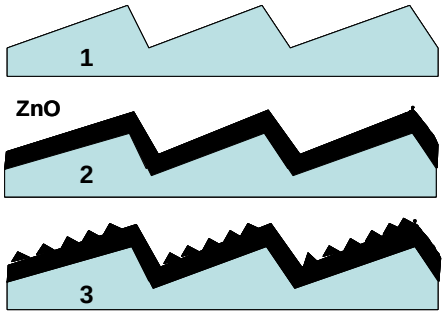
Work Package – 2 (WP-2)

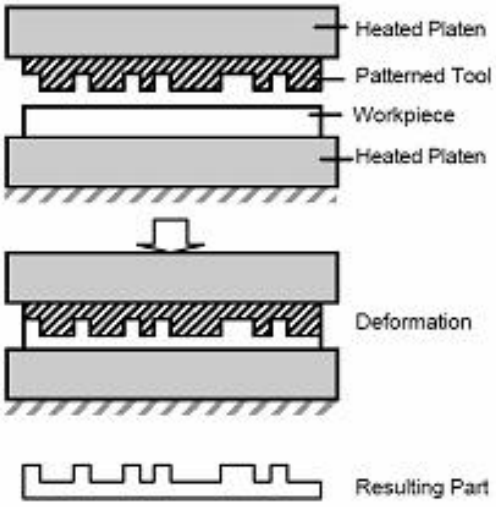
Micro Process Technology for Hot Embossing Tool Development

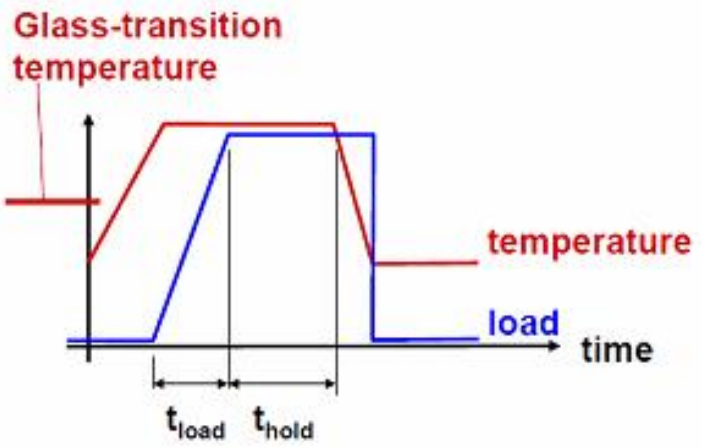
- Objectives
  - To develop an appropriate micro/nano fabrication process to manufacture relatively larger stamps (tool inserts) to use in hot embossing of glass.
    - Development of hybrid micro technology for making embossing tool
    - Investigations on embossing tool materials for the glass substrate
    - Manufacturability evaluation of hot embossing tool with the designed geometrical features
    - Characterization of embossing tool including process modeling
- Leading Partner & PI
  - Central Mechanical Engineering Research Institute (CMERI), Durgapur
    - Dr. Nagahanumaiah, Scientist–F, Micro Systems Technology Lab.
- Participating Partners
  - Central Glass and Ceramic Research Institute (CGCRI), Kolkata
  - Bharat Heavy Electricals Limited, Bangalore

Hot Embossing over glass

- Glass is a key material in the PV industry (2005 demand for PV glass=12mn m^2).
  - High durability and transparency.
  - Requirement for PV glass maximum transmittance over a selected wavelength range.
  - Iron content is the strongest contributor to absorption and gives glass its characteristic green colour. To enhance transmittance, iron is reduced from over 1000 ppm to less than 100 ppm.
  - Antireflective coating to the outer surface of the glass to reduce reflectance losses
  - In CIGS technology which uses a molybdenum reflector to start the vertical integration.

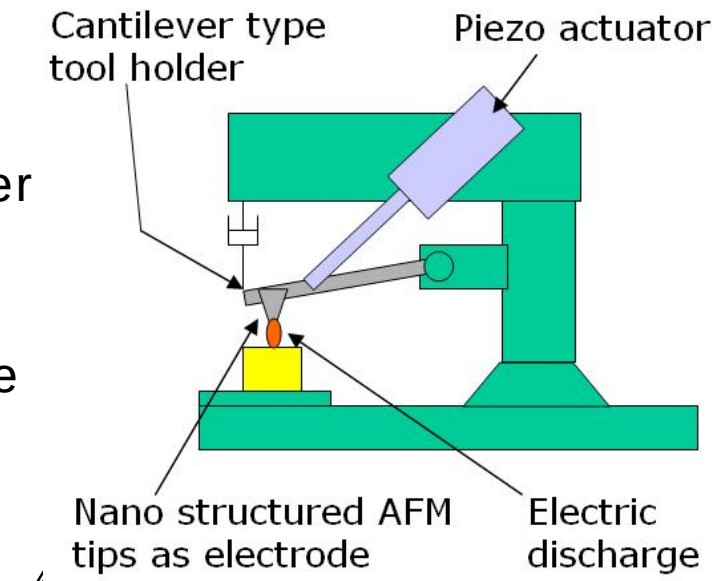






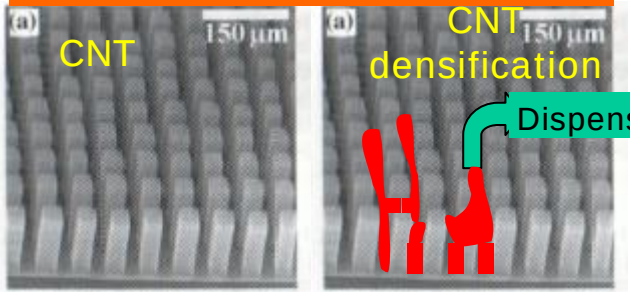
Proposed Micro-Nano Scale Fabrication Technologies

- Nano scale EDM
  - Single electrode nano-EDM
    - Modular cantilever based tool holder embedded with nano structured AFM tips
    - Nano structuring of AFM/alternative material tool tips using FIB
    - Nano-EDM power circuits for single and repetitive discharge
  - Parallel spark discharge across nano structured multi electrodes (large area tools)
    - Bunched CNTs as electrode
    - Nano structured tungsten carbide electrodes



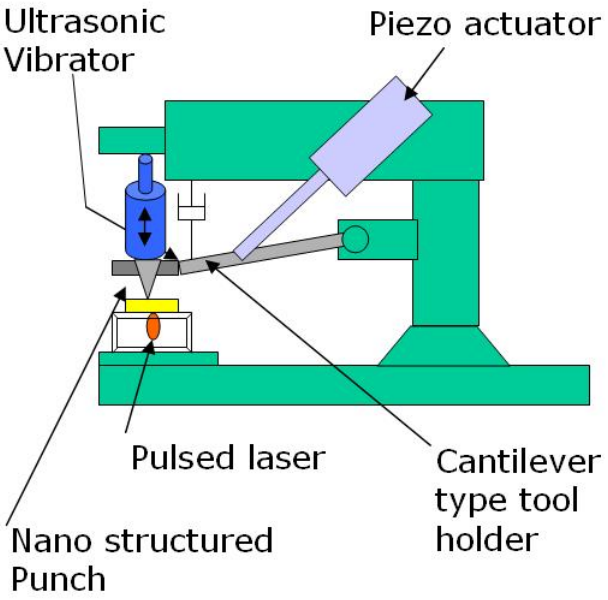
Replace with

CNT electrodes for nano-EDM



Proposed Micro-Nano Scale Fabrication Technologies

- Laser assisted nano-imprinting on tool insert
  - Modular cantilever tool holder embedded with nano structured AFM tips
  - Nano structuring of AFM/alternative tool tips using FIB Nano structuring of imprinting tool
  - Laser assisted imprinting
- Repeated Electro-Chemical etching
  - Nano positioning system mounted with portable DC powered electro-chemical etching unit
  - Masking of tool surface
  - Atomized single drop controlled electrolyte pumping
  - Repetitive etching



About Leading Research Group

Micro Systems Technology Lab.

- Research Focus
  - Micro-Nano Scale Processing and Engineering of the systems (micro machines) in the dimensional scale of 0.01-500µm.
  - Micro-Nano fluidic lab-on-chip based devices
- Manpower: 4 scientists, 2 tech.staff 6 students and proj. staff
- Current research projects
  - Modular Reconfigurable Micro Manufacturing Systems (MRMMS): NWP30 (11th FYP network project CMERI, CEERI, CSIO and NAL)
  - Membraneless Micro Bio-Fuel Cell with Self Pumping Mechanism - OLP190312
  - Adhesion, dewetting and contact line study on micro-nano fluid employing molecular simulations and CFD (OLP 190712)
  - Fiber bragg grating based sensor for micro tools health monitoring (Approved under NIMITLI: Jointly with Prof. S. Asokan, IISC, and M/s. Scientific Instrumentation Pvt. Ltd. Bangalore)
  - Advanced grating for thin films solar cell (Approved under Indo-European Call on Solar Energy Systems 2010)

Research Projects

- Modular Reconfigurable Micro Manufacturing Systems (MRMMS): NWP30 (11th FYP network project CMERI, CEERI, CSIO and NAL)
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Micro Machines & Subsystems

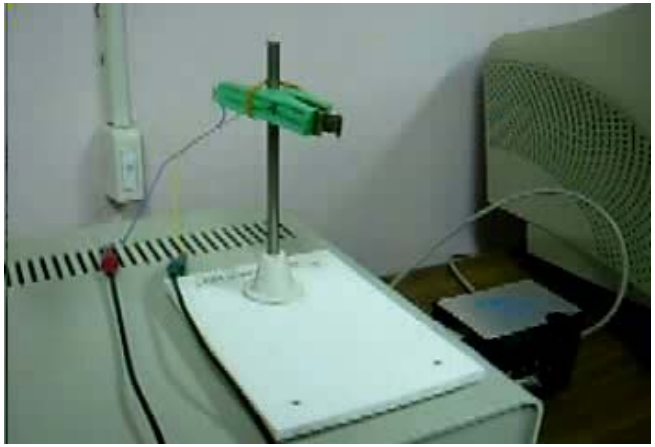
- Micro machines
  - Micro EDM-Milling Machine
  - 5-axis Micro Milling Machine
  - Multi-Purpose Micro Scale Laser Processing Machine
  - Reconfigurable Micro Factory Test bed
- Key processing technologies
  - Platinization of Nafion to develop IPMC actuators
  - Selective laser sintering of for metal powder <10µm powder
  - Parallel spark multi tool EDM for higher productivity
  - Synthesis of 30nm scale Alumina powder by solution combustion method
- Micro elements and subsystems
  - Miniaturized High speed spindle (Pelton wheel based design): 275k RPM
  - Linear positioning stages with air bearing
  - IPMC based micro gripper and manipulator for micro parts handling
  - Prototype software system for part family formation operation clustering in reconfigurable micro manufacturing systems
  - Embedded control systems for micro manufacturing systems

Micro Machines and Systems

(Working Prototypes)

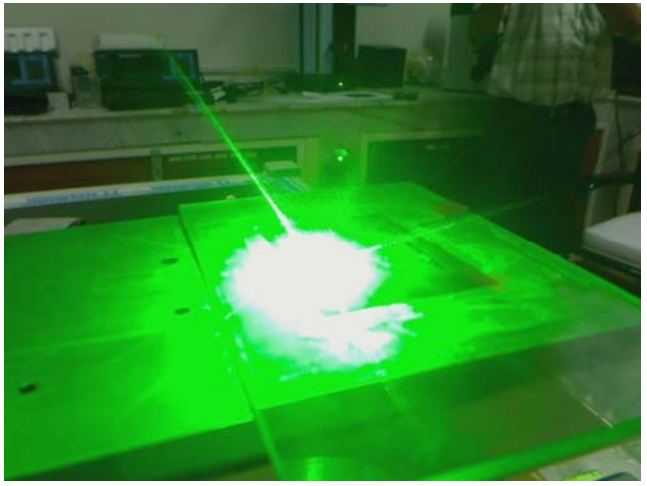
5-axis µ-mill

IPMC actuator



µ-Laser Processing System

µ-EDM machine

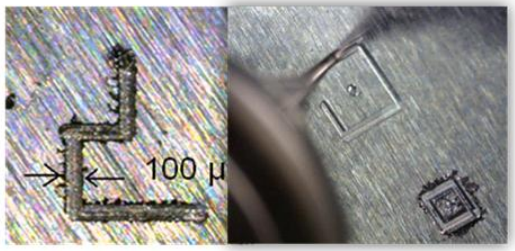


Micro Machines and Systems

(Working Prototypes)

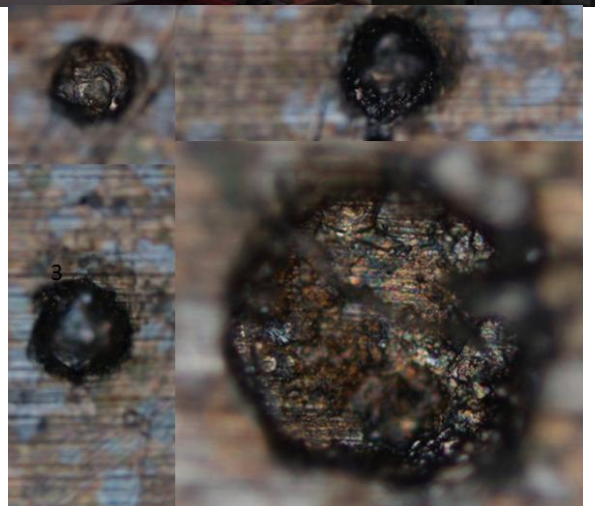
5-axis Micro *µCNCmill* in operation

GUI of *µCNCmill* Control System



Micro milling experiments

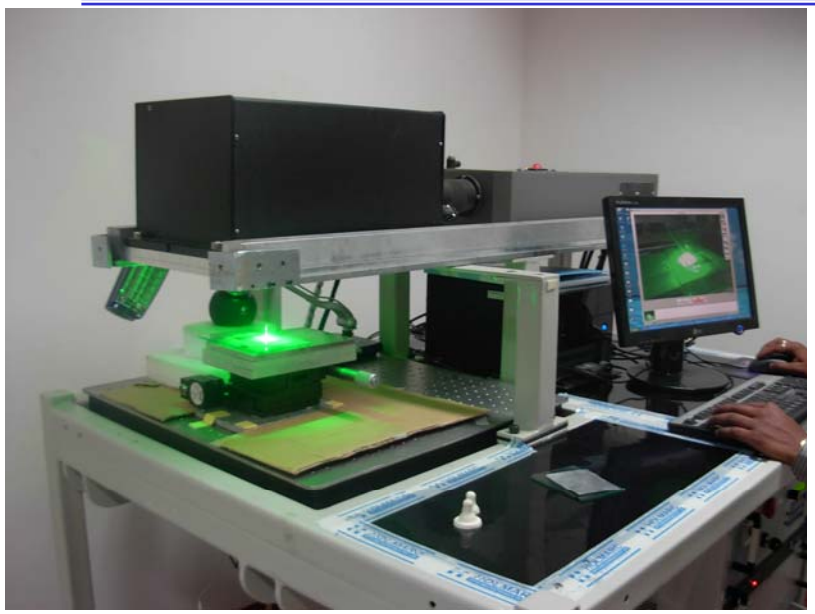
5-axis µ-milling machine prototype



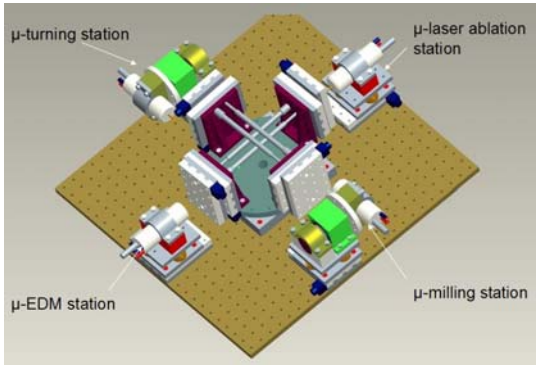
µ-EDM machine prototype

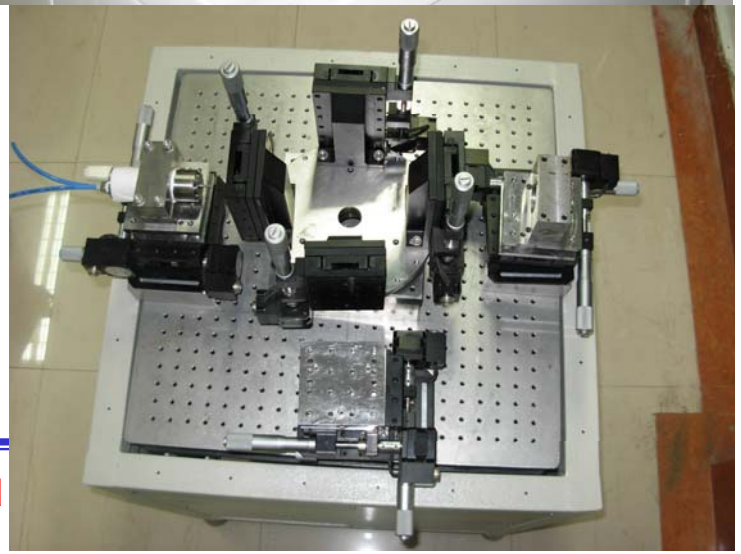
Micro Machines and Systems

(Working Prototypes)



Micro Laser Processing System multipurpose operations

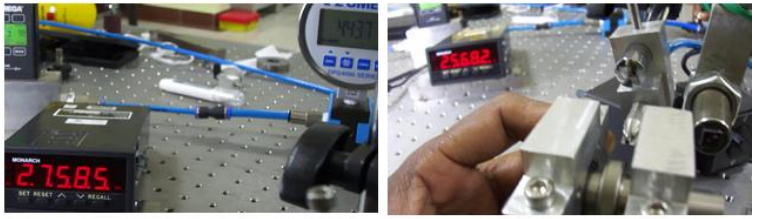




Reconfigurable Microfactory testbed

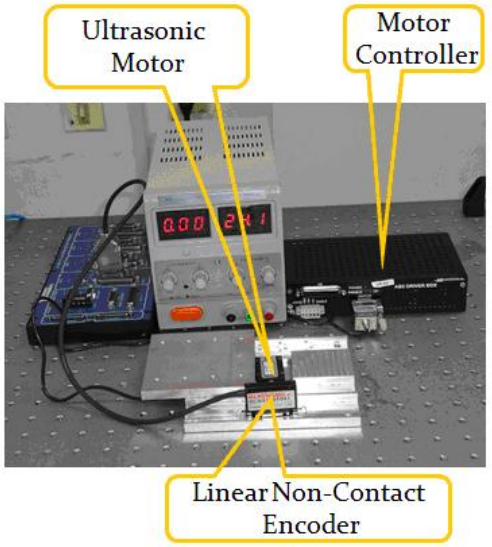
Micro Machines Elements and Subsystems (Working Prototypes)

Pelton wheel based Air Turbine

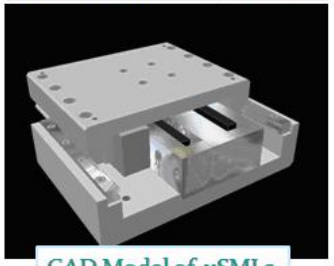


Experimenting at 275k rpm

Pelton Wheel based High Speed Spindle



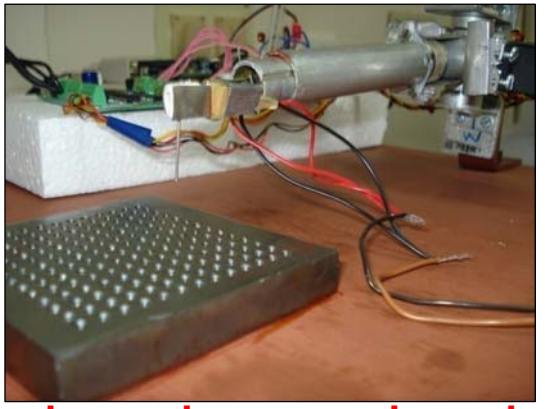
Specifications	
Travel Range	60mm
Min Resolution	50nm
Driving Force	16 N
Max Velocity	250m/s
Repeatability	0.5µm



CAD Model of µSMLs

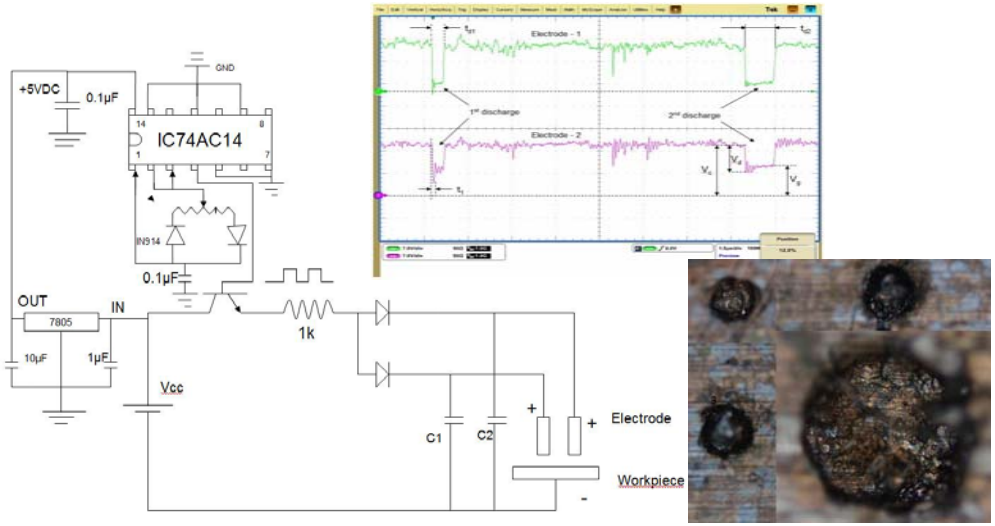
Precision Linear Stage with air bearing

Micro Assembly Workcell

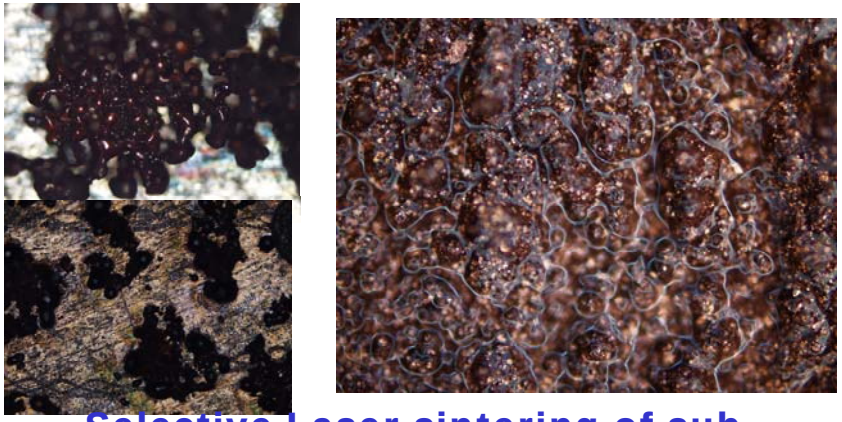


IPMC micro grippers and manipulator

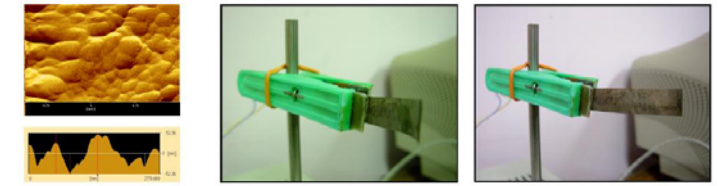
Process Technologies



Multi tool parallel spark µ-EDM

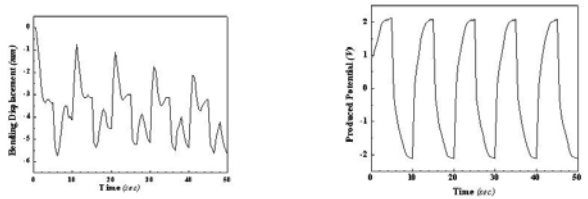


Selective Laser sintering of sub-micron (5µm) Copper powder



Surface Morphology

Actuation of IPMC at +3V and -3V



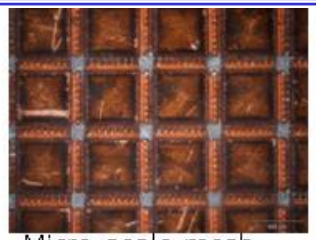
Bending displacement and change in potential under a square pulse signal applied using chrono-potentiometry for 5 sec of duration with ± 100 mA input current.

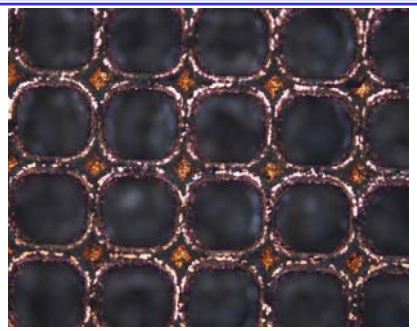
IPMC: Platinization of Nafion Polymer

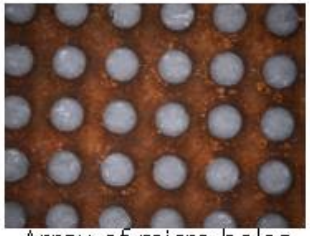
Synthesis of nano scale Alumina by solution combustion method

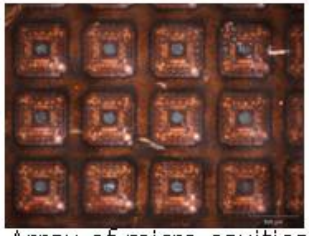
Micro Machining Capabilities

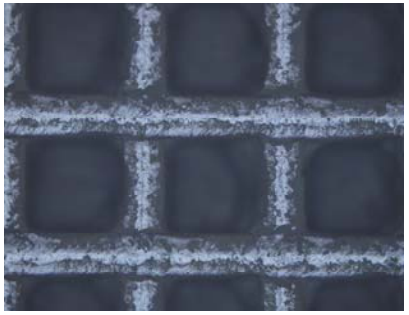

Honeycomb structure

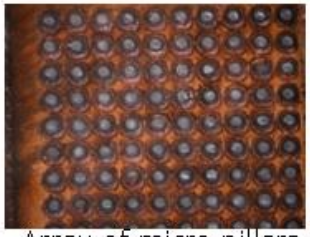

Micro-scale mesh



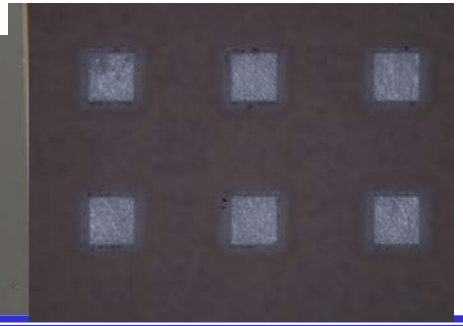

Array of micro holes


Array of micro cavities




Array of micro pillars


Array of micro pillars



- Micro milling of 3D features
  - Channels:100µm, holes:150µm diameter in 1mm thick plate
  - Material: Metals, polymers, green ceramics, metallic glass, etc.
- Micro EDM-milling of 3D features
  - Channels and holes : 20µm on Copper, 50µm on aluminum
- Pulsed Laser Ablation
  - 50µm size 2D features with complex geometry up to the aspect ratio of 200.

RP-III: Micromachines and Processes for Larger Area Nano-Structuring

(Research Components and Methodology)

CMERI, CGCRI, CEERI, CSIO, NAL, IMMT

Application Areas

Bio-Medical Application

- Antibacterial surfaces: protection from secondary infection
- Electronically controlled drug delivery systems
- Adhesives, etc.

Energy Systems

- Solar cells: Thin films, Substrates
- Pro-bacterial surface for bio-energy harvesting, etc.

Automotives

- Substrates for long last coatings
- Nano cooling and lubricated triobological surfaces, etc..

Security / strategic

- Smart Textiles
- Optical mirrors
- Display systems

Primary Objective

Micromachines and the process technologies for generating nanosurface features of <100nm over 50mmx50mm area

Work Packages

WP-I	WP-II	WP-III
Nanosurface Processing Technologies	Integrated and Modular Micromachines	Micromachine Subsystems (Operation enabling kits)

Research Tasks

WP-I

- Pulse modulated nano scale EDM
- Nano inks and printing technology
- Self Assembly of metal-organic framework
- Selective laser metal deposition
- Pulsed electro deposition of nano composites
- Bio-functionalized nanosurfaces and interfaces
- Micro powder injection molding
- Vibro-mechanical texturing of surfaces and interfaces
- Nano structuring by synthesis of special materials

WP-II

- Precision machine design methodologies
- Ultra precision drives and controls
- Self adoptive controls
- Gas lubricated precision bearings micro mechanical systems
- Magnetically levitated contact less bearings for micromachines

WP-III

- Nanolubrication and Cooling systems for meso-micro mechanical systems
- Dry/thin film lubrication of mechanical systems
- Ferrofluids enabled micro machines supporting elements
- Machine vision system for process monitoring
- Nano measurement and characterization
- Micro part handling and assembly

Thank You