विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

सत्यमेव जयते

# DST – NFTDC Centre for Materials & Energy Storage Platforms on Hydrogen

DST – NFTDC MECSP / H2

## DST – NFTDC MECSP / H2

DST – NFTDC Centre for Materials & Energy Storage Platforms (MECSP)‘ involves **graduation from TRL – 3 to TRL – 7**, wherein multitude of core competencies (differentials) are brought together in a solution path integral. This TRL 3 to 7 translational R & D is predominantly anchored on Material - Process – Product integration and optimization involving and dovetailing many materials and processes in a functional product design as systems.

The Projects are executed under three work packages :

**WP#1: Bio Syngas & CNG Reformation System + CHP & BOS for SOFC System**
**WP#2 : Magnesium – Carbon based $H_2$ Storage Systems Development**
**WP#3: Metal – Hydride Sorption Cooling based on Waste Heat / Solar Thermal (CSH) – Materials, Design and Device Development**

Three work packages are inked via five institutions focusing on **Materials – Process – Product Integration**.

**CONSORTIA**

## NFTDC|IISc|IITM|IITBBSR|SCTCE

# QUOTES

“The collaborative platform provided by the centre would bring best minds together and is expected to lead to research and technology outputs of immense value for clean energy driven growth. This would also accelerate innovation in clean energy domain for cost effective, reliable and robust solutions”.

Dr. Harsh Vardhan
Union Minister for Science & Technology, Earth Sciences, Environment, Forests and Climate Change- Government of India

“Development of efficient and effective materials is essential for innovations in clean energy domain. The centre would strive to address the gaps and address the residual research challenge to provide end to end solution through interdisciplinary research network”

Prof. Ashutosh Sharma
Secretary to the Government of India,
Department of Science and Technology

NFTDC’s mandate is Technology Development and Translational R&D with emphasis on product – process integration and optimization in particular in materials to system level solutions. In line with the ethos of systems approach and end to end technology development in TRL 3-7 spectrum, this consortium addresses all crucial elements in technology development of Energy Devices with focus on generation, storage and utilization of Hydrogen in an integrated manner. Successful prior work in TRL 3 - 4 levels in all three above areas by consortium partners has been the foundation of this centre which now is embarking on a major challenge of materials to system level device development endeavour in three specific product verticals, namely integrated SOFC device with in-situ hydrogen generation, cost-effective solid-state storage solution and hydride-based cooling.

Dr K Balasubramanian
Director, NFTDC and Head DST-NFTDC
Centre for Materials & Energy Systems – Hydrogen

Conduct state of art **TRL 3-7 translational R & D** in Materials to $H_2$ based Energy Devices in the area of SOFC, H2 Storage and Metal Hydride sorption cooling

Conduct Research & Development of **novel materials** as composites, graded materials, mixtures, materials + catalysts around the well – proven base materials to meet the figure of merit for **SOFC, H2 storage and Metal – Hydride sorption cooling**

OBJECTI VES

# OBJECTIVES OF THE CENTRE

Develop cost effective processes for synthesis, deposition, thermal treatment, thermo-mechanical processes, joining, precision manufacturing and assembly for enabling both **materials development** and their **scale – up** on one hand and **materials to products** manufacture on the other

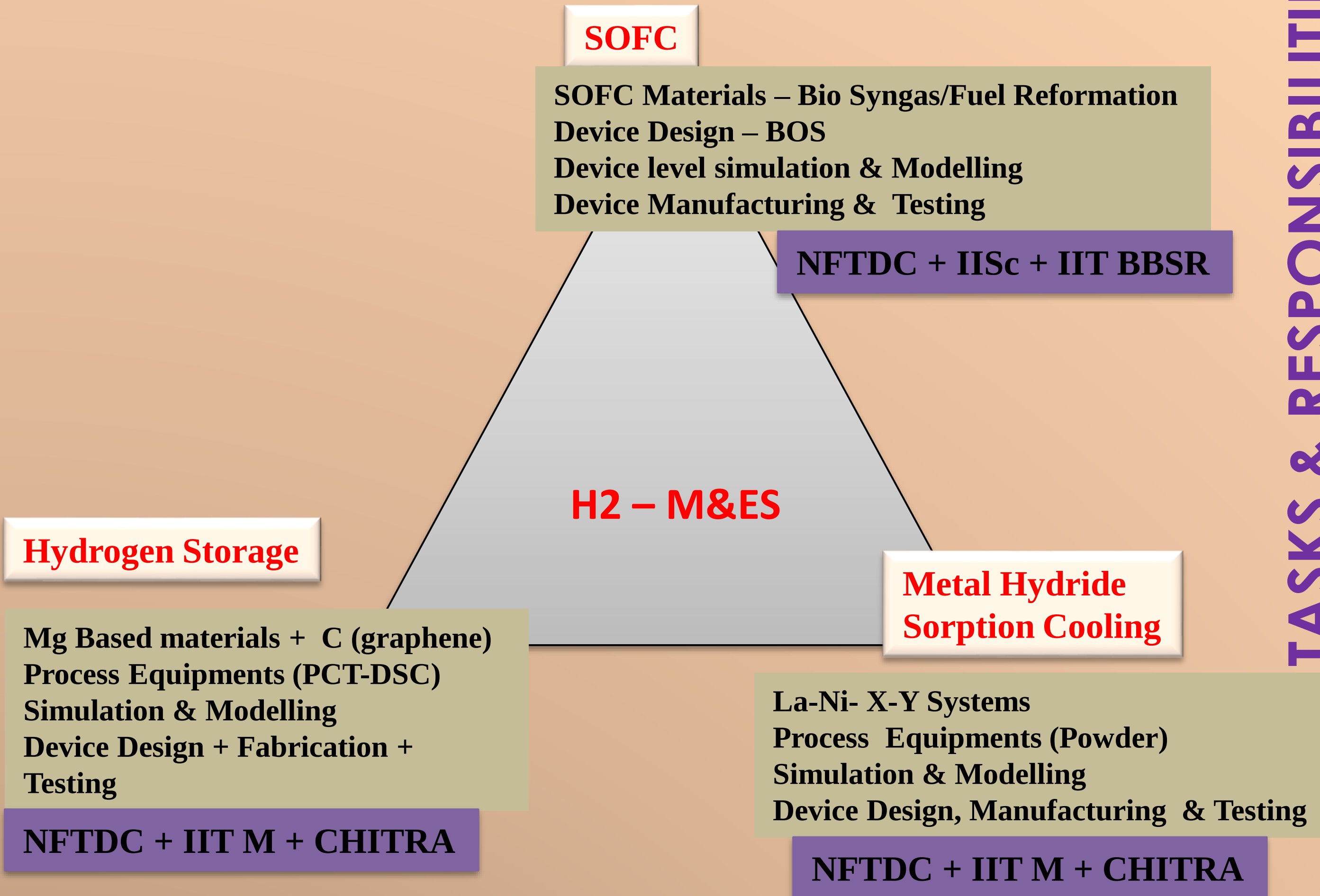
Develop innovative designs and design for manufacture **(DFM & DFA) of energy devices** and conduct extensive simulation and modeling to distil high performance design configurations;

Design, develop and fabricate **cost effective process equipments** for materials synthesis and manufacture of devices

Render device designs in a **process – product integration and optimization paradigm** in TRL 4-6 translation to manufacture prototypes;

- **BOS** and **BioSyngas & CNG Reformation** and undertake larger system level development and eventually graduate to TRL -7 pilot production of SOFC devices.
- **Develop functional test – beds and conduct long duration testing of the device**; integrate the device in field level applications;
- **System level modeling and simulation** to iterate the designs to optimize the performance parameters of efficiency, cycle life, ease of manufacture and cost metrics;
- **Upgrade pilot plants and establish pilot plant for scale – up of advanced materials** RE oxides, catalysts, RE alloys to ensure supply chain based on indigenous RE materials;
- **Study techno – economics for feasibility** of large scale product manufacture and market acceptance;
- To **conduct focused workshops on SOFC, H2 storage and Hydride Sorption cooling.**
- To **train the next generation researchers in SOFC, H2 storage and Hydride Sorption** and develop system level thinking and engineering
- To **interact with energy companies** in India and abroad to **translate product to business**

TASKS & RESPONSIBILITIES




# Macro Tasks + Shared Responsibilities

Four centres, **IISc, Bangalore, IIT M, Chennai, IIT Bhubaneswar and Sree Chitra Thirunal College of Engineering, together with NFTDC** have appropriate core competence, decade(s) of experience, infrastructure facilities and proven track record to handle the problems chosen in this consortium.

# FACILITIES & TASKS



## IIT M

H2 storage + Sorption Cooling

Simulation & Modelling

(software + Workstations)

Lab Scale Apparatus

Validation

TRL 3 & 4

## Sree Chitra

H2 storage + Sorption Cooling

(software + Workstations)

Systems Level Modelling

TRL-3

## NFTDC

Materials & Catalysts

Pilot Plants

Process Equipment

Engg Design + Fabrication

Device Design & Development

Test Beds &

Long Duration

Testing

TRL3-7

## IISc

(SOFC)

Bio Syngas Production Facilities

In-situ Reformation Kit

SOFC Stack Design Validtaion for Effective Fuel Utilization

Test Beds

TRL 3 to 6

## IIT BBSR

SOFC – Material Synthesis Equipments & Facilities

Extensive Materials Characterization Facilities

Cell Level Studies

TRL3 & 4

# Reformation, CHP & BOS for SOFC System

WORK PACKAGE -1

# WORK PACKAGE – 1
# SOFC Systems

***NFTDC | IISc | IIT BBSR***

**Target Device**

- Bio Syngas reformation kit; CNG reformation kit
- 1 kW & 5kW SOFC stack as CHP System
- BOS >> Power Electronics (DC-DC & DC-AC)
- Cell: 0.9 -1.0 V & 60 Watts (100 x 100 mm)

**Materials & Components**

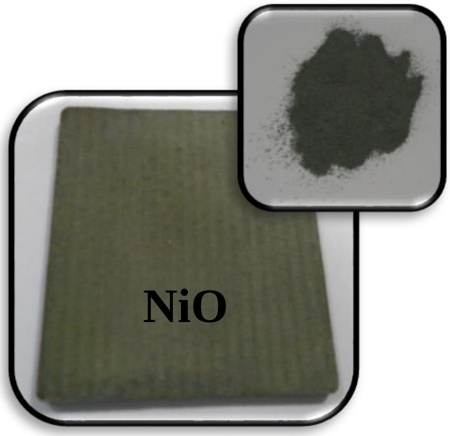
- Porous SS / Ni metallic foam anode support (area 80x80/100x100 mm)
- NiO/GDC (Gadolina doped Ceria) anode & LSCF cathode
- GDC as electrolyte & YSZ as interlayer
- Stainless Steel as interconnects.
- Active brazing materials (TiCuSil); Silicate insulation seals

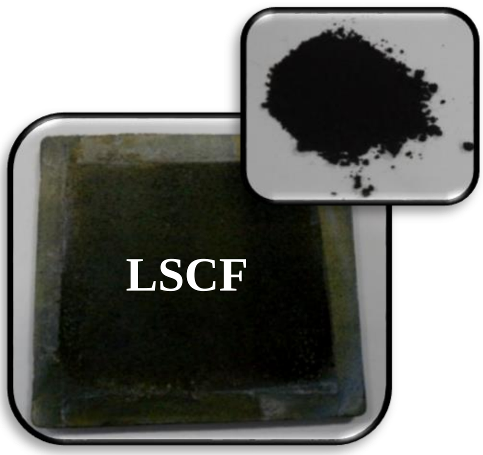
- **Apparatus:**
- Modification of **Plasma Gun** for liquid + solid spray deposition
- Design and Development of **Ink Jet Printer nozzles**.
- SOFC Stack level **Test Bed** for fuel optimization & SOFC performance

- **Integrated SOFC BOX with all of above connected to Demonstration Load`**

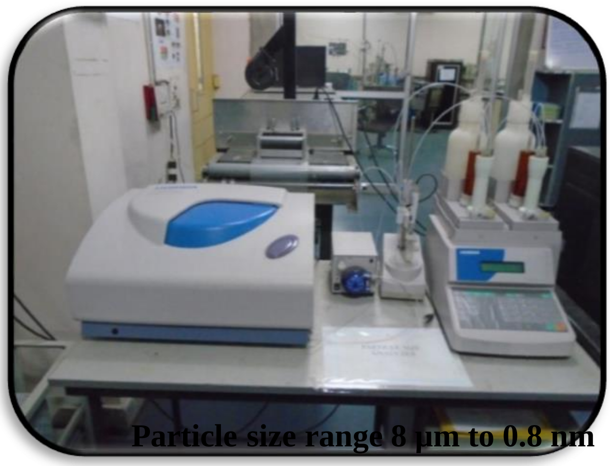
WORK PACKAGE -1

## Input Powders (15-20 kg/batch) Synthesized in NFTDC


### Particle Size Analyzer



Particle size range 8 µm to 0.8 nm

## Facilities: NFTDC >>Powder Production & Heat Treatment Processes

**Jet mill >> powder Preparation**

- **Vacuum >> $10^{-5}$ mbar**
- **Max T >> 1500°C**

**HV-HT Furnaces for heat treatment**

- **Particle size 2 micron**
- **Batch size up to 8 Kg**

**Helium leak detector**

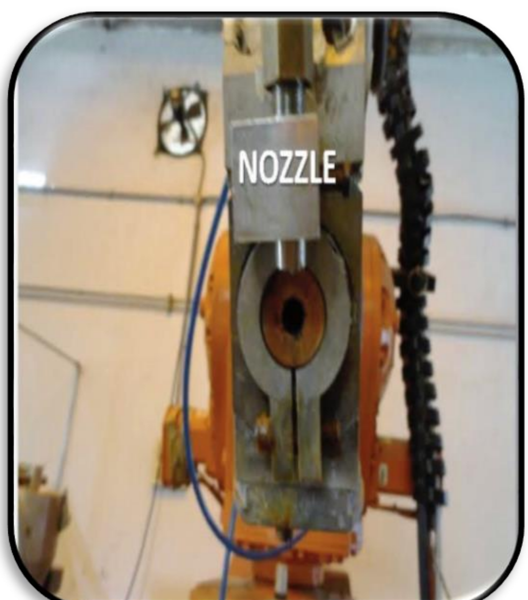
- **Leak detection**
- **$1X10^{-12}$ m.bar.lit/sec**

# Facilities: NFTDC >> SOFC Cell  Fabrication

**Thin film &  micro manufacturing**

**Ink Jet Printer - 16 nozzle assembly**
**(Deposition : 0.5 µm / layer)**

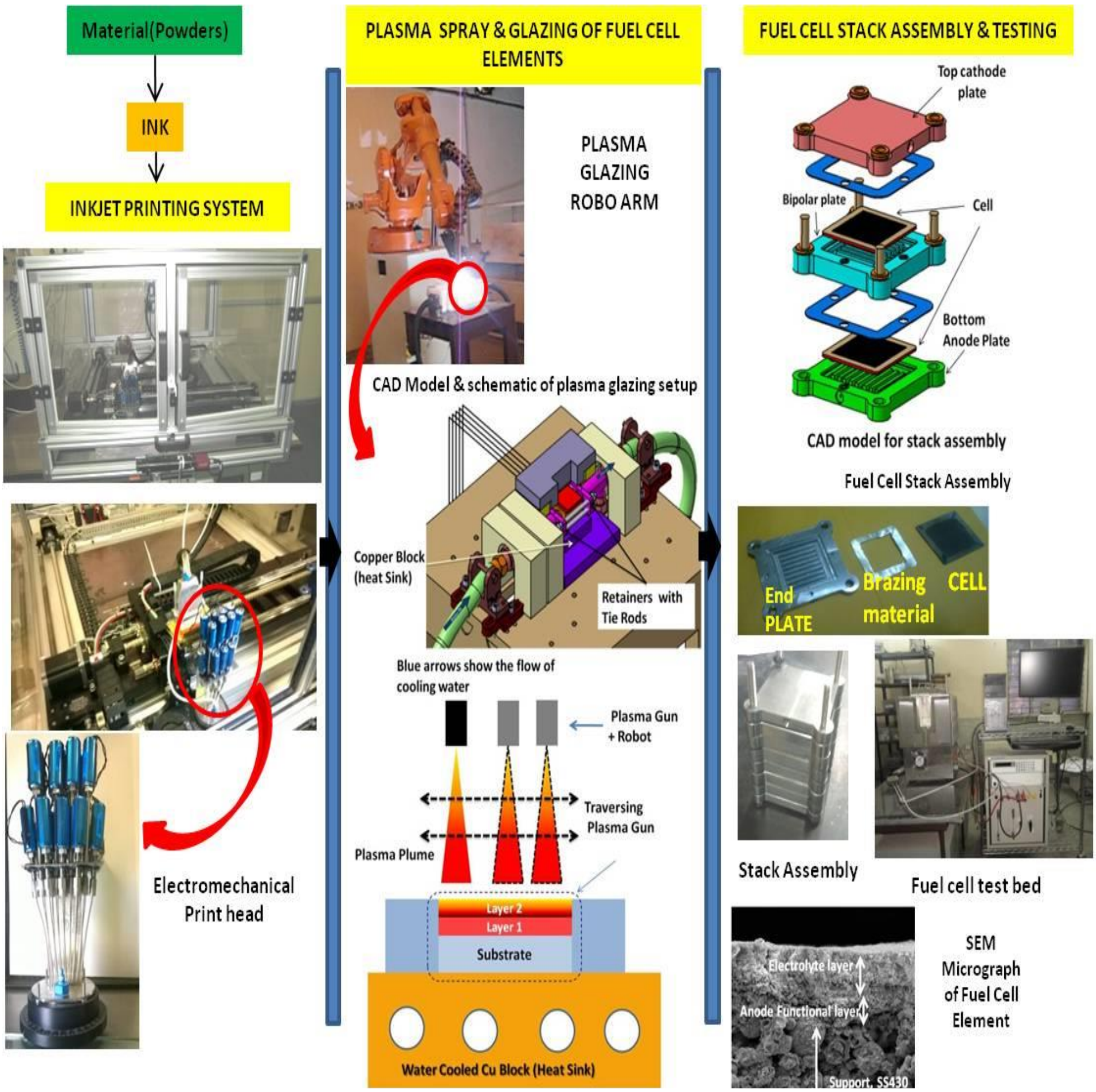

**Plasma Spray Equipment + Robotic Arm**

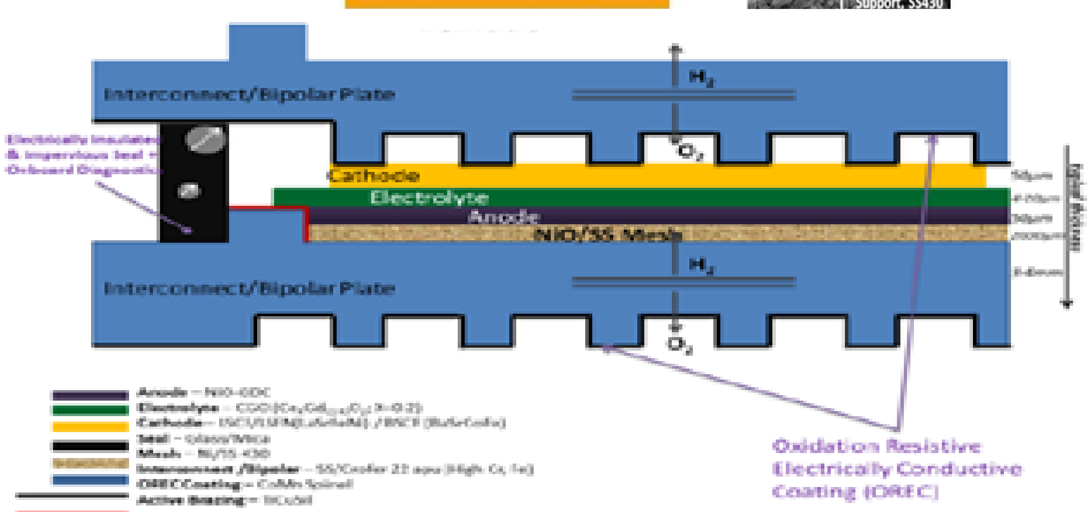



**Plasma Gun Nozzle with Liquid Precursor or Powder  Spray Deposition (2 – 5  µm / layer)**

WORK PACKAGE -1

# Process Flow from Materials to SOFC Stack >> NFTDC



# Facilities: IISc >> Biomass to Syngas Fuel to SOFC Stack

WORK PACKAGE -1

Inputs to Biomass Gasification


1 kW Biomass Gasification System

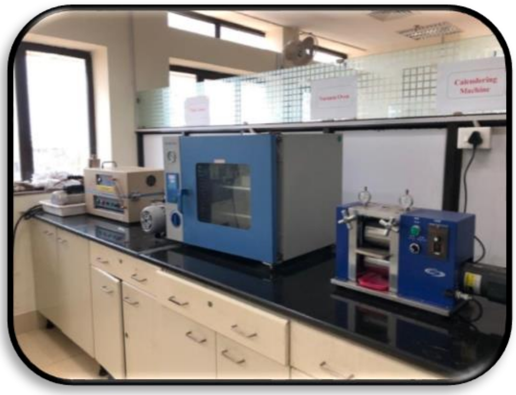
10 kW Biomass Gasification System

SOFC Test Bed

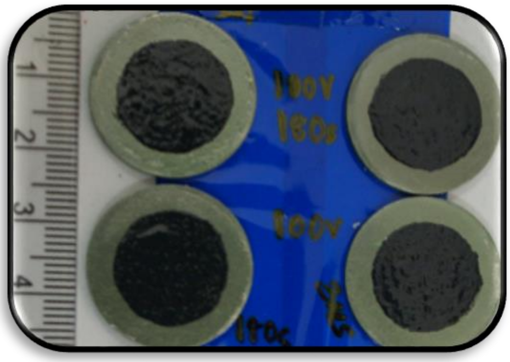
Gas Chromatograph

# Facilities: IIT BBSR >> Materials to Button Cells & Characterization

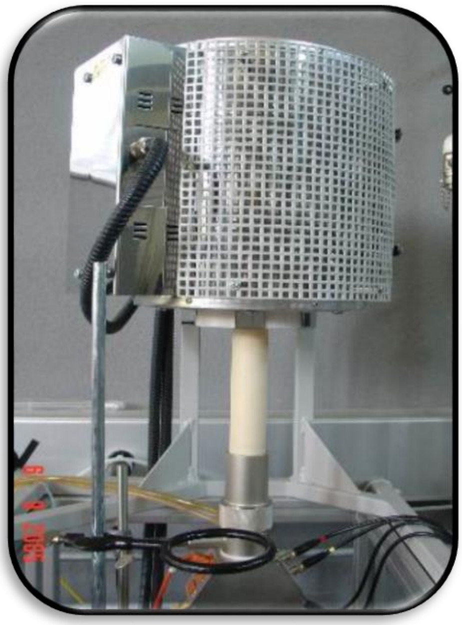
WORK PACKAGE -1



Cell Fabrication Set-up



Button Cells



Testing Facility

H2 Storage – PCT Apparatus

DSC / TGA Equipment

Electrochemical Station

# Magnesium – Carbon based $H_2$ Storage Systems Development

WORK PACKAGE -2

# WORK PACKAGE – 2

# Hydrogen Storage Systems

***NFTDC | IIT M | Sree Chitra Thirunal***

**Target Device:**

- Storage Device Biomimetic Design; Modeling & Optimization
- Adiabatic Solutions
- Fabrication (35 – 50 grams of $H_2$) with heater (max 300$^{o}$C)

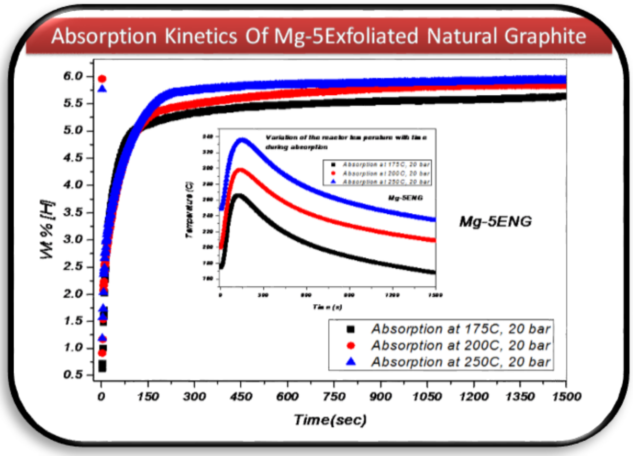
**Materials:**

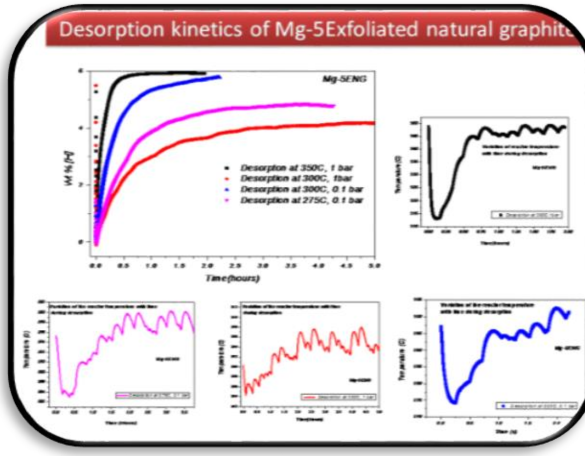
- Mg + Graphene (1 - 5 wt%)
- Mg + Graphene + Dopants (B, N, P)
- Mg + Expanded Graphite (5Wt%) + dopant (B, N, P)
- Mg + Intermetallics + Carbon (Doped Graphene or doped ENG)

**Apparatus:**

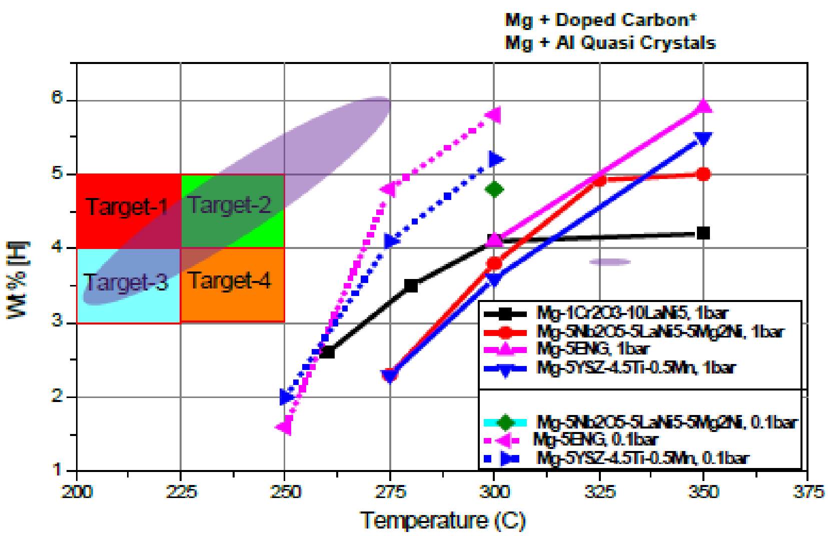
- Microwave – plasma based Graphene Production Apparatus
- PCT – DSC

# Sample Results of Magnesium – Natural Graphite System

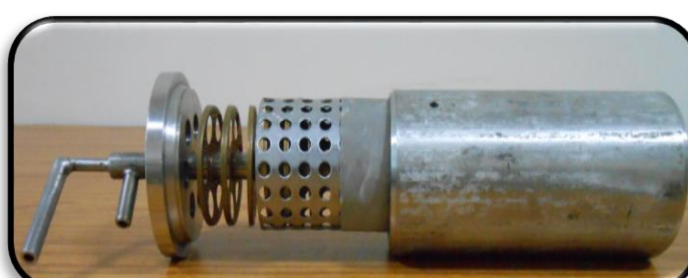


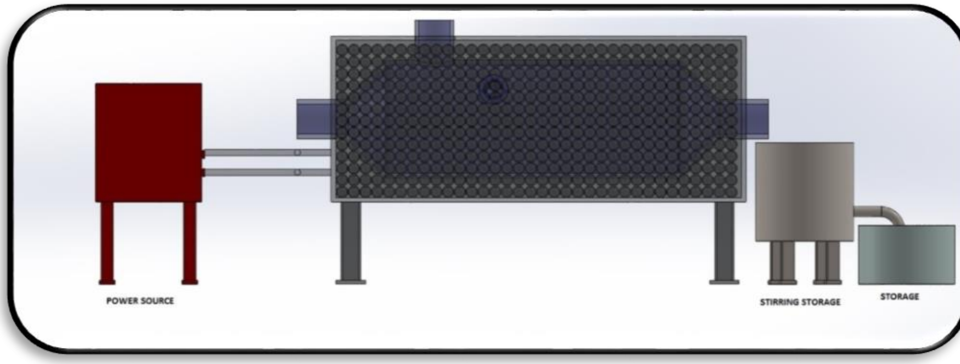

## Magnesium – X system: Present Scenario vs Target to be achieved

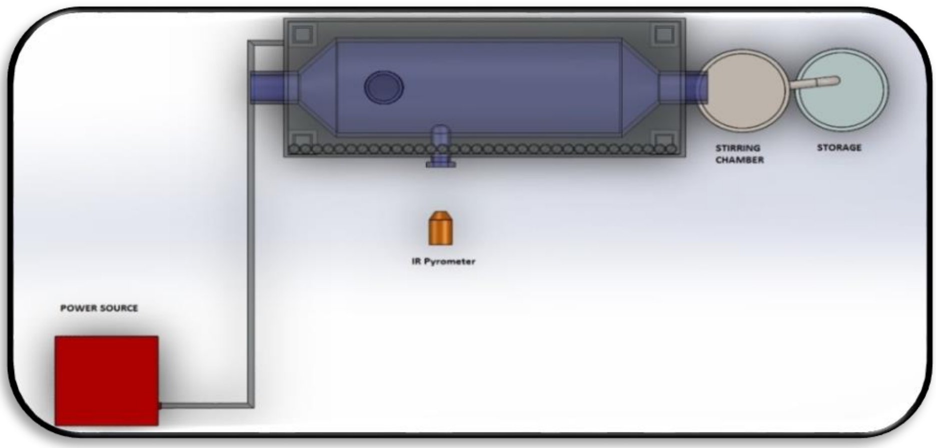



## First Iterations of Experimental Hydrogen Storage Devices

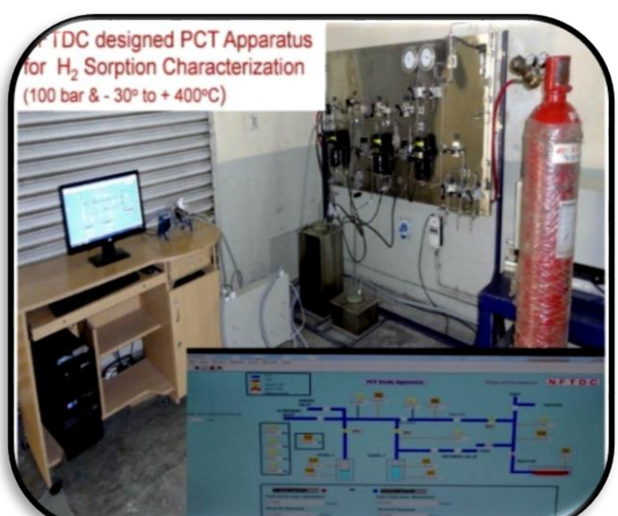



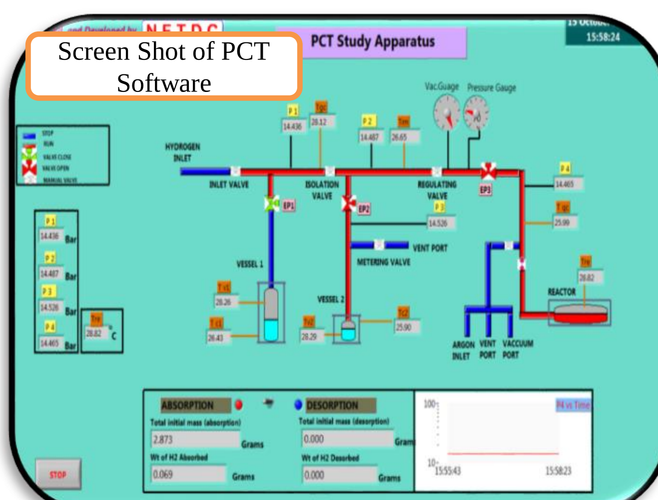
# Model of Equipment for Graphene Production – under design at NFTDC




# PCT Apparatus and User Interface developed at NFTDC

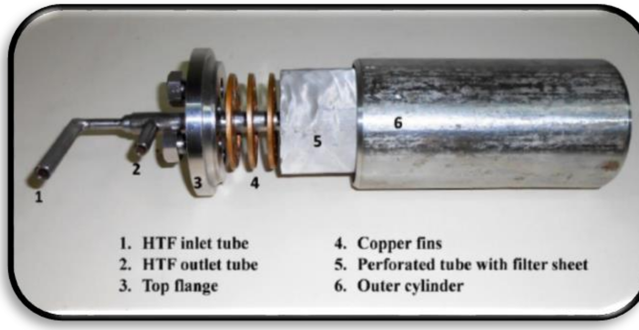


# Facilities: IITM >> $H_2$ Storage Materials to Device

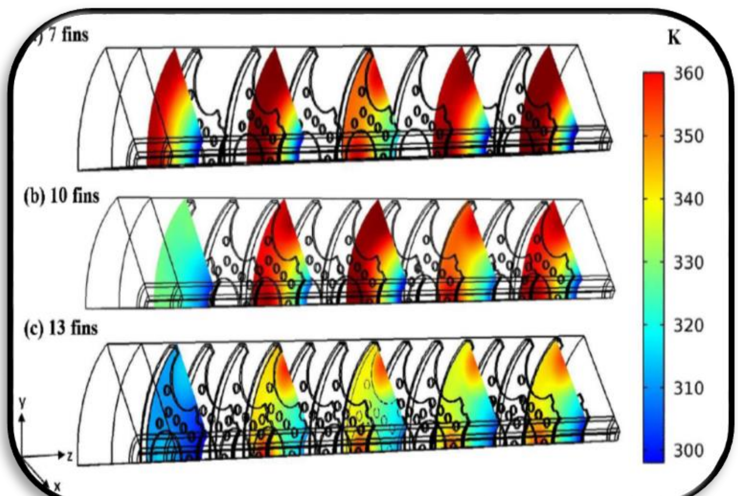
WORK PACKAGE -2


1. High pressure hydrogen cylinder, 2. Pressure transducer ($P_1$), 3. Mass flow meter ensor and transmitter, 4. Pressure transducer ($P_2$), 5. Storage device, mostatic bath, 7. Vacuum pump, 8. Pirani gauge, 9. Data acquisition sy




**H2 Storage Reactor Prototype - 1**

**Hydrogen Storage Facility**




**Temperature Distribution model of fins used in Reactor**


**Prototype – 2 after optimizing Thermal design of Reactor**

# Metal – Hydride Sorption Cooling based on Waste Heat / Solar Thermal (CSH) – Materials, Design and Device Development

WORK PACKAGE -3

# WORK PACKAGE – 3
# Metal – Hydride Sorption Cooling

***NFTDC | IIT M | Sree Chitra Thirunal***

**Target Device**

• Biomimetic Design of Cooling Device: Carrier; $H_2$: 2mm dia; Waste Heat: 3-6 mm dia; Device: diameter = 50 -80mm; length = 250 – 400mm

• Prototype Device with twin cartridges (HT & LT) coupled to waste heat source & $1m^3$ volume to be cooled from $40^oC$ to $15^oC$ as demonstration.

•Two prototype configurations >> cabin and automotive application space.

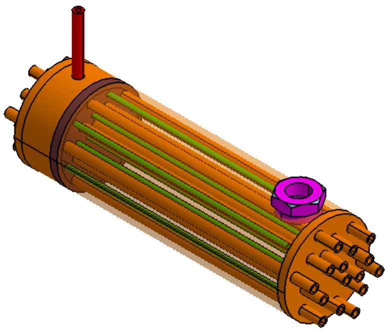
**Materials**

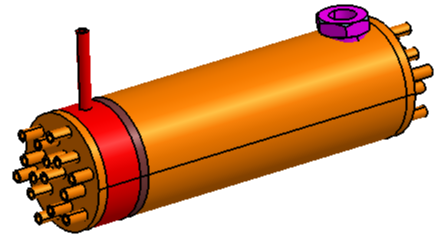
- La – Ni – X (Al, Ce, Fe); 4 Compositions;
- per cartridge: 1.5 - 1.7 kg HT and 0.8-1.0 kg LT

**Apparatus**

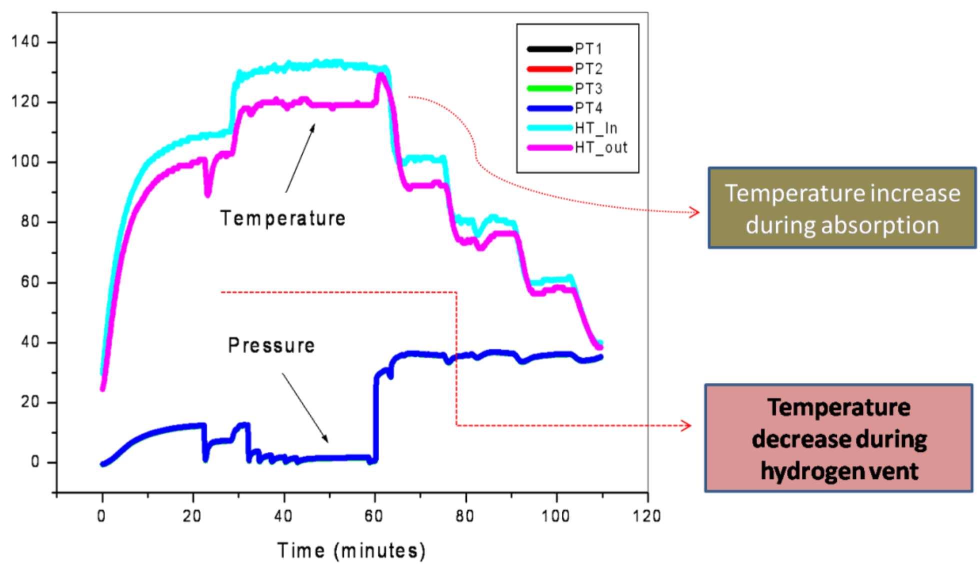
• Centrifugal Powder Preparation Apparatus for 1 kg powder/run.
*Attributes*: T $2000^oC$ max); Induction heating; Vacuum + Ar;
Multi-layer crucibles to hold & spin liquid melt; ceramic nozzles
Run Time 30 minutes charge to charge; rpm 300 – 500;

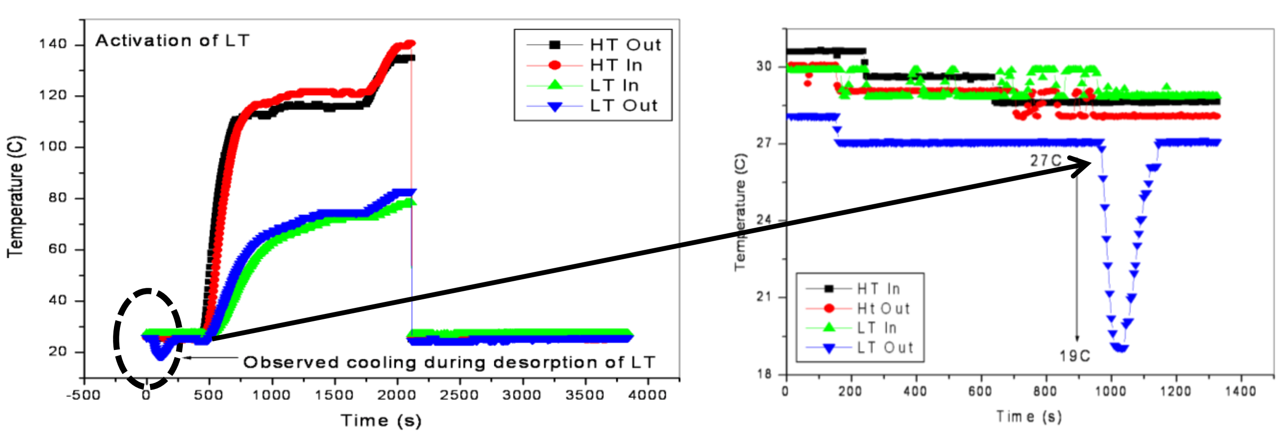
# Biomimetic Design of Cooling Device - First Iteration





## Sample Results of HT – LT System using Metal – Hydride




**T - decrease 8°C per unit air volume in circulation per cycle**

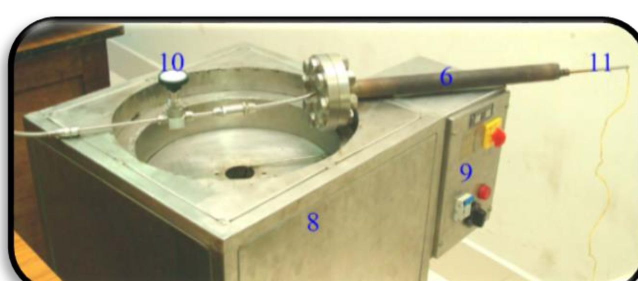
# Facilities: IITM >> Powders to Sorption Cooling Device & Characterization

**Planetary Ball Mill**

**Attritor Mill**

**Static & Dynamic PCT Measurement**

**Effective Thermal Conductivity Measurement**

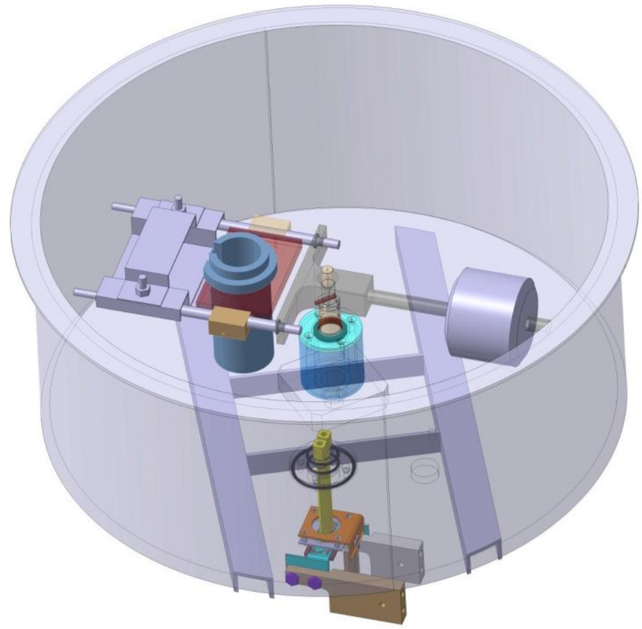




**Hydrogen Storage Experimental Facility for Metal Hydrides**

WORK PACKAGE -3

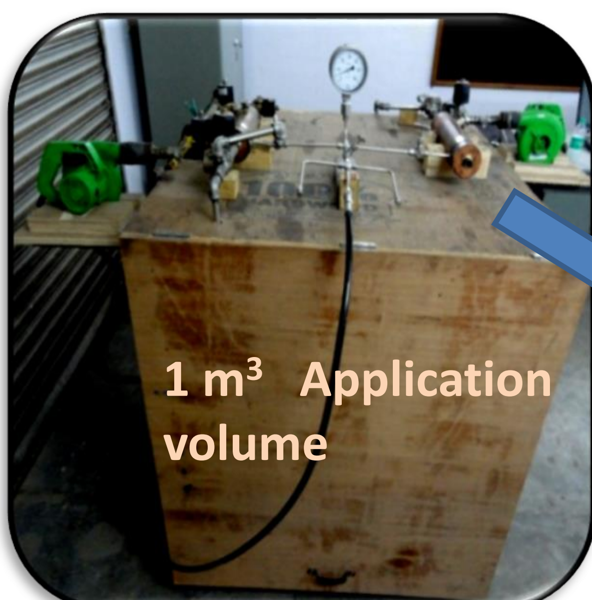
# Facilities: NFTDC >> Materials to Device

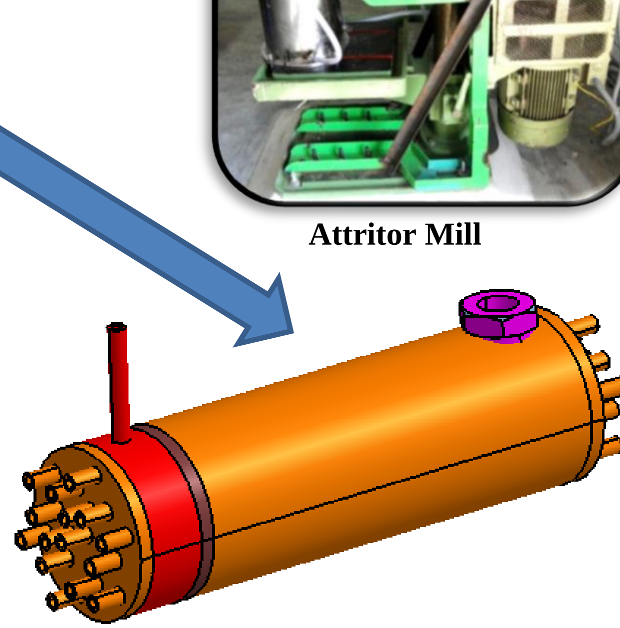
10 kW Induction Melting System



Vacuum Centrifugal Caster – Concept Design

Attritor Mill

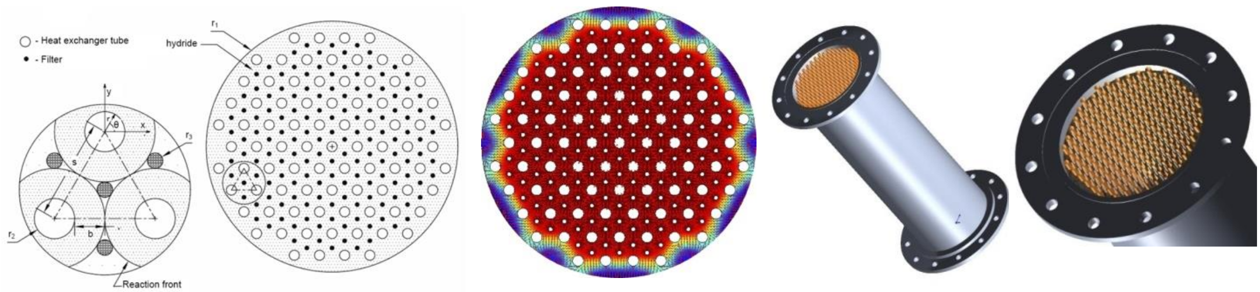


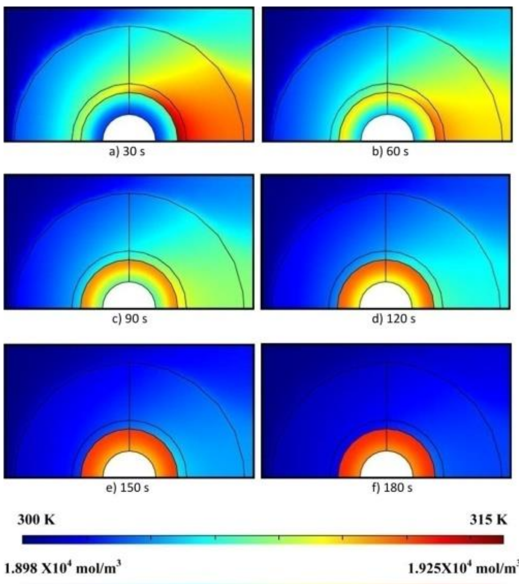
1 $m^3$ Prototype of Metal – Hydride based Cooling Set-up

# Modeling & Simulation: Sree Chitra Thirunal College of Eng

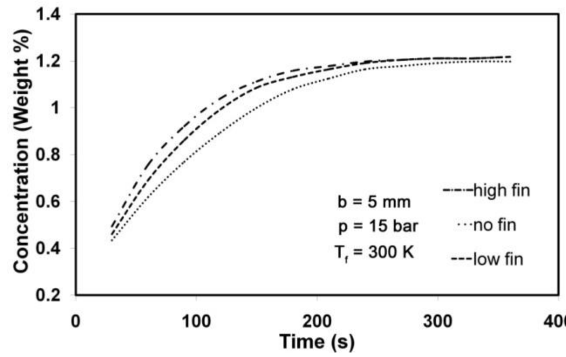
WORK PACKAGE -3



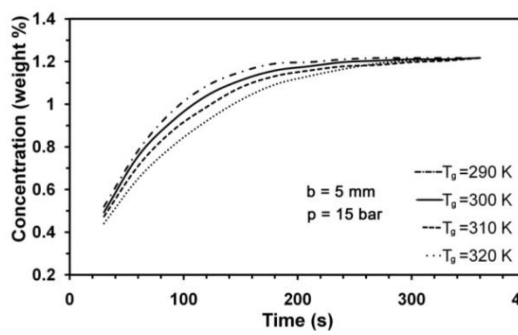

**Numerical Study of Metal Hydride Storage Device with Embedded HX Tubes**



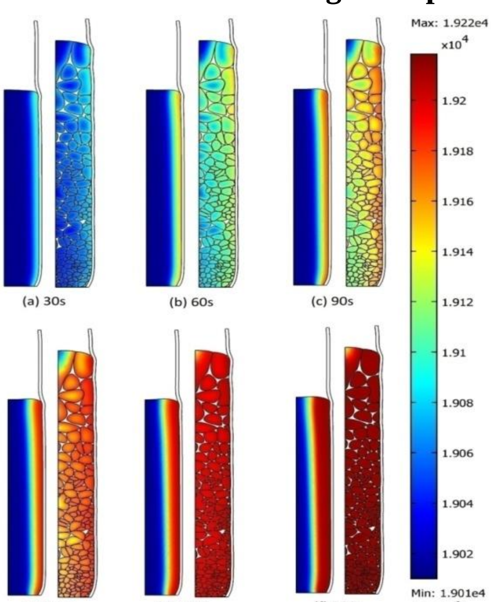

**Formation of hydride inside tubular storage within the air stream during absorption**



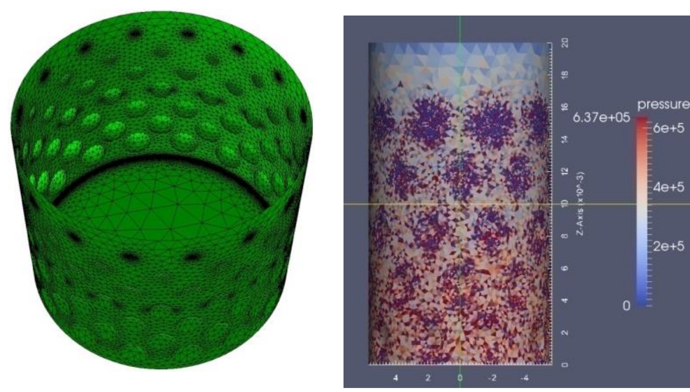

**Effect of external fins on rate of hydride formation**




**Effect of air temperature on hydride formation**




**Spatial variation of concentration in MH bed with Aluminum Foam (p=15 bar, $T_f$=300 K)**




**Wall Stresses in Metal Hydride Container with Dimples**

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NFTDC, Hyderabad

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IISc, Bangalore

Prof. S. Dasappa

Co – PI
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Prof. MP Maiya

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IIT Bhubaneshwar

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Co – PI
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College of Engineering,
Thiruvananthapuram

Prof. G. Mohan

MATERIALS
DESIGN
CONTROLS
(KNOWLEDGE)
NFTDC

*Conceptualized by:*

***Dr. Ranjith Krishna Pai***

***Dr. Sanjay Bajpai***

Ministry of Science and Technology
Government of India

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