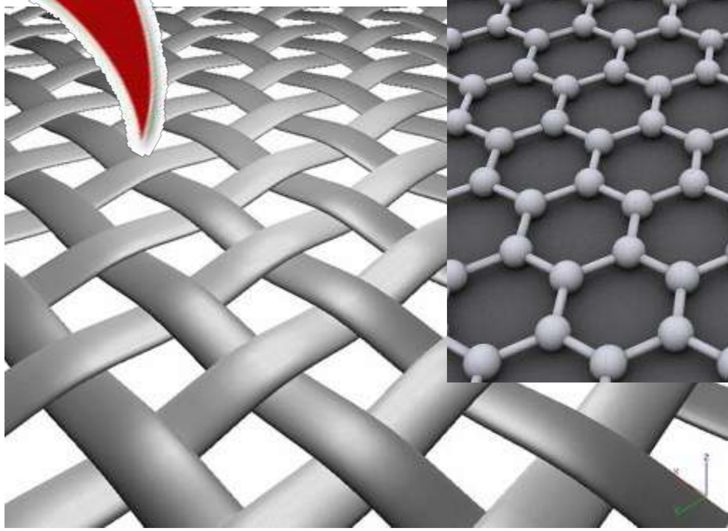
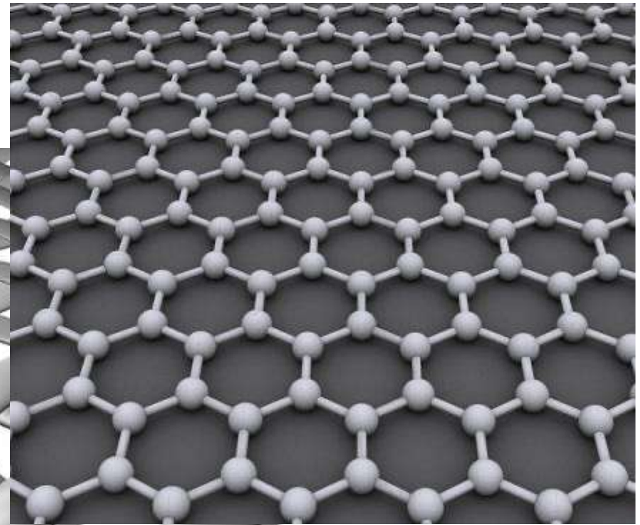
institute IMDEA materials
UNIT OF EXCELLENCE MARÍA DE MAEZTU





DISEÑO Y RENDIMIENTO DE COMPUESTOS ESTRUCTURALES LIGEROS

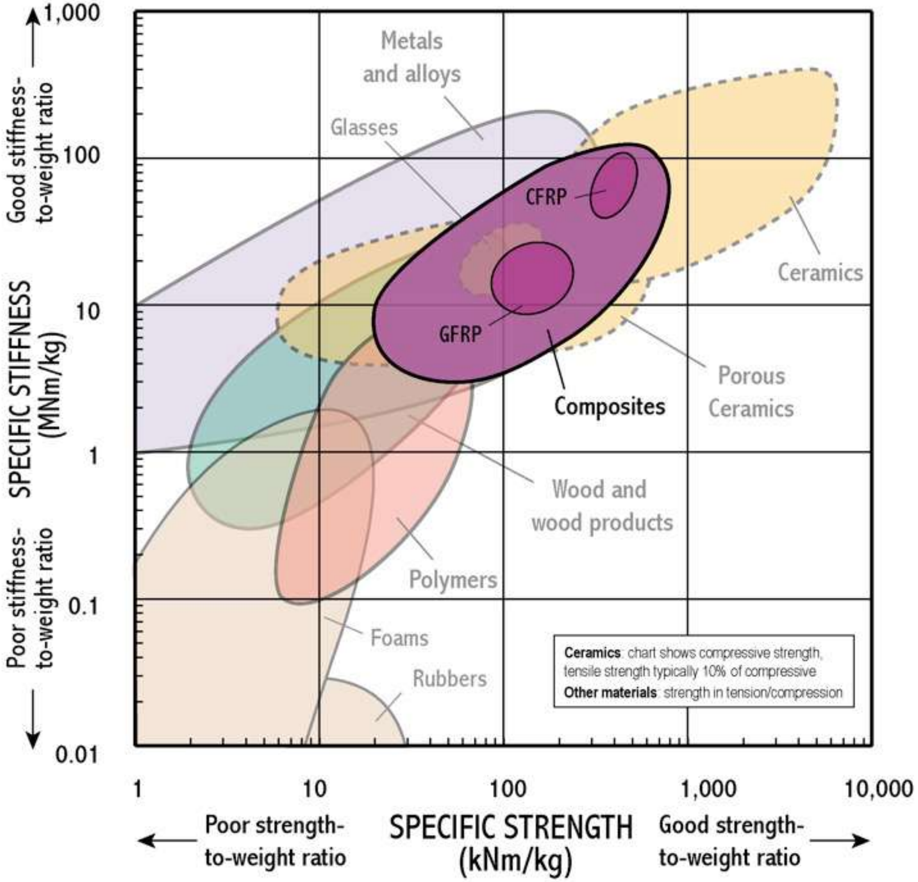
MATERIALES PARA UNA MEJOR DEFENSA

Academia de Ciencias y Artes Militares (ACAMI) y el Instituto IMDEA Materiales

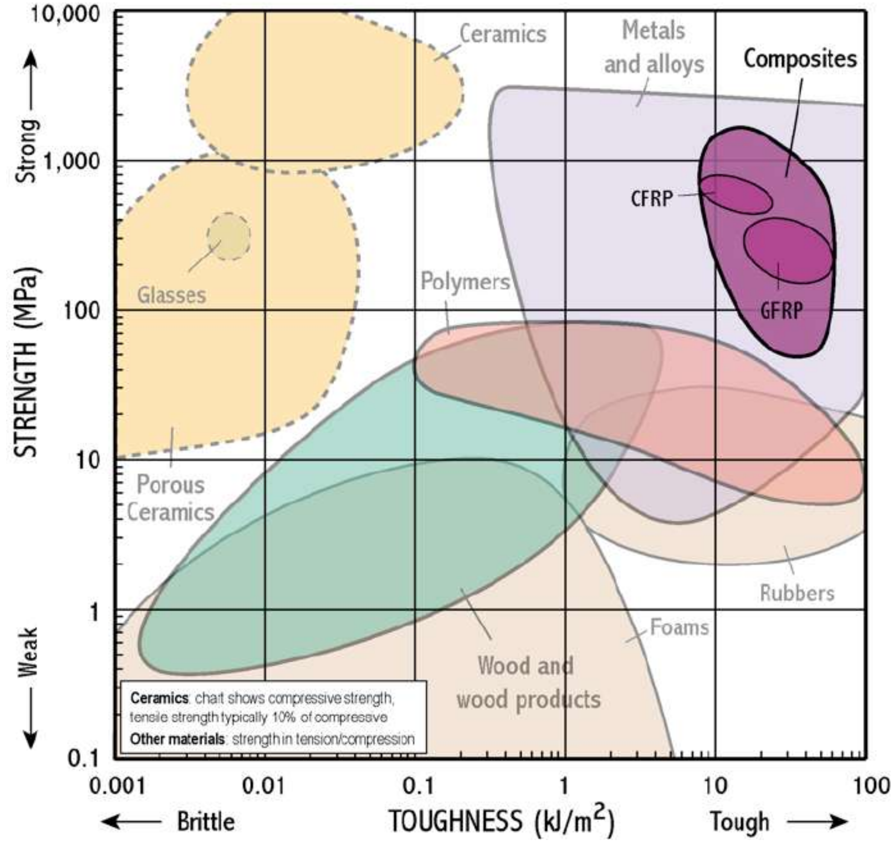
Carlos González

WHY COMPOSITES?

Stiffness/strength

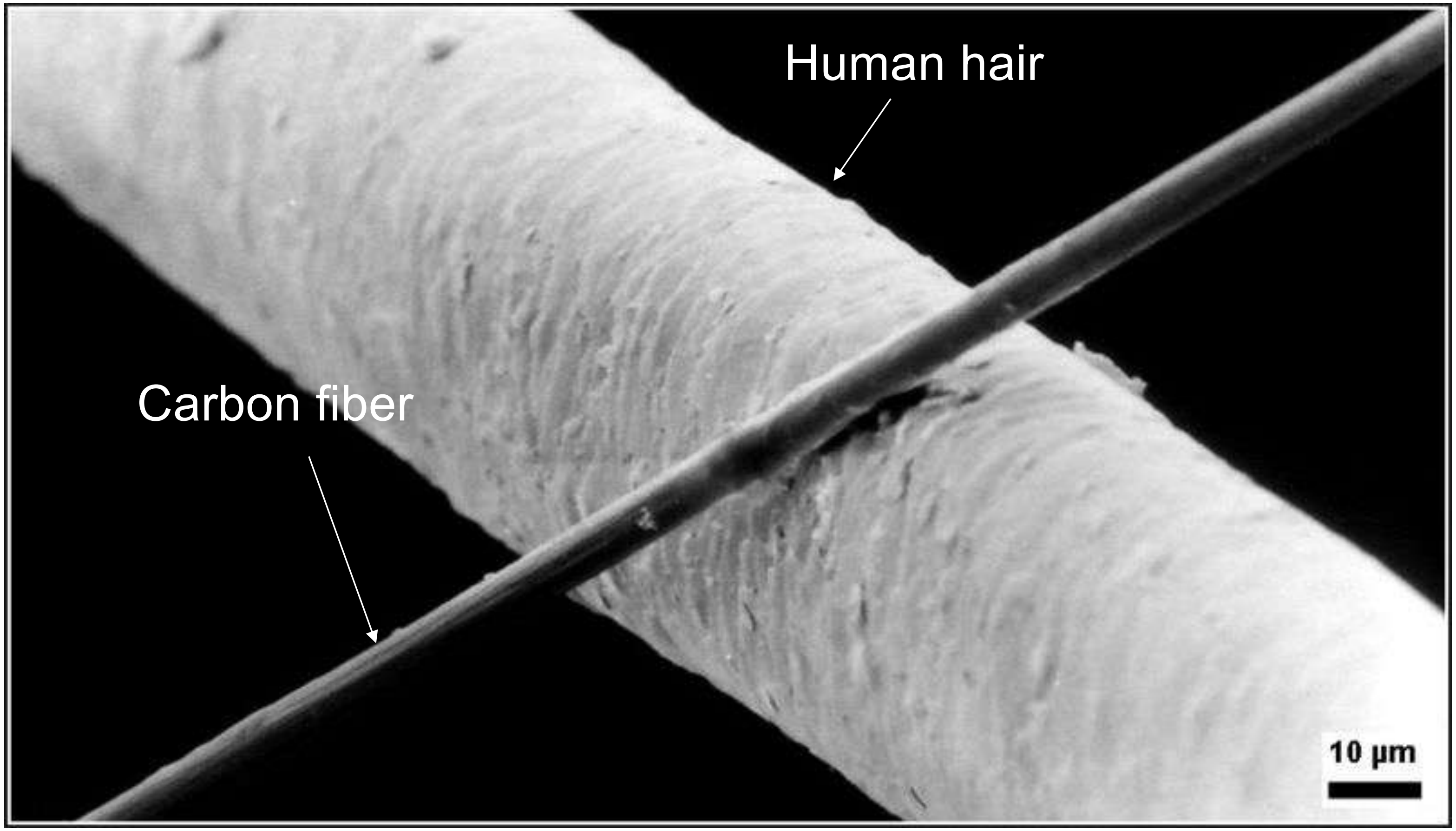


Strength/toughness



imdea materials institute
UNIT OF EXCELLENCE MARÍA DE MAEZTU

WHY COMPOSITES?



WHY COMPOSITES?

Natural fibers

- animal: silkworm silk, spider silk, wool
- plants: cotton, yute, wood
- cellulose

Synthetic

- basalt, quartz, glass
- aramid
- carbon
- nylon, polyester, polyethylene
- PBO

glass

basalt

carbon

sisal

alpaca

UNIT
OF EXCELLENCE
MARÍA
DE MAEZTU

sports

automotive

energy

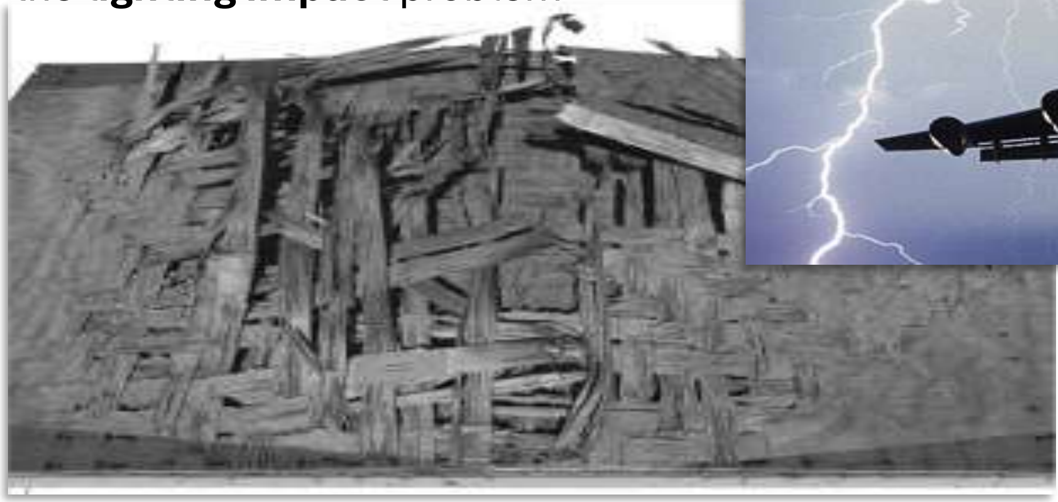
defense

aircraft

space

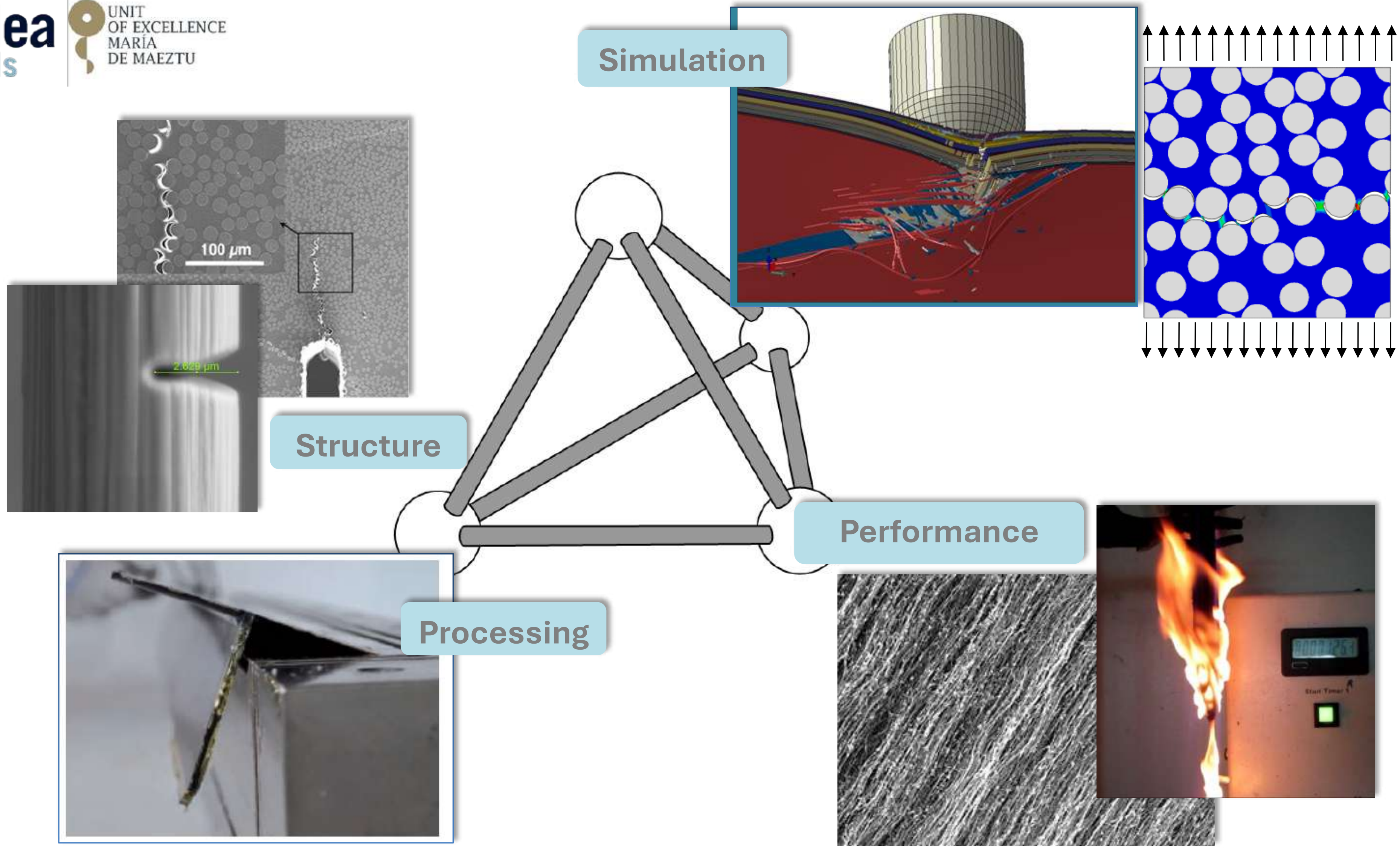
MISSIONS OF THE STRUCTURAL COMPOSITES GROUP

A real industrial example:
the **lighting impact** problem



High strength structural composites with improved electrical conductivity

- To push up the **current performance limits** of composites
- To integrate **innovative functionality** of composites
- To develop **material concepts** and their **manufacturing routes**


Simulation
100 µm
Structure
Processing
Performance

Processing

RTM&Infusion

Structural Integration

Vacuum Bag & Autoclave

Processing of High Performance Composites

Processing of High Perfomance Nano Composites

Injection Molding

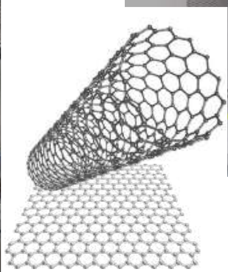
Extruder

Microcompounding

Calendering

Processing of Advanced Carbon Fillers

Nano Carbons reactors



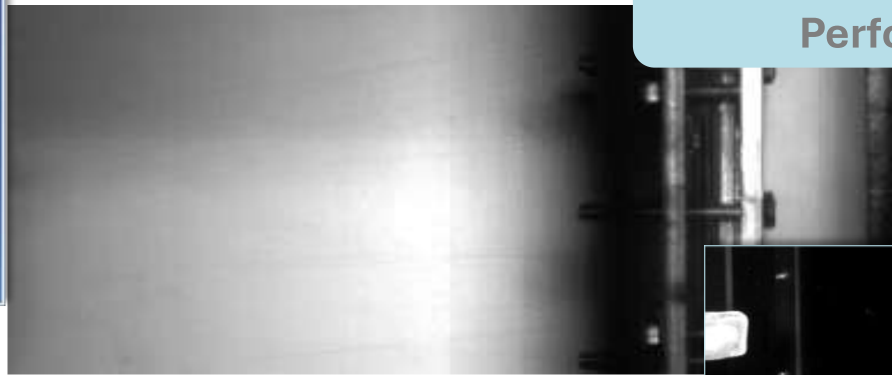
Performance

New frontiers of Structural Performance

Structural Composites for Impact Applications

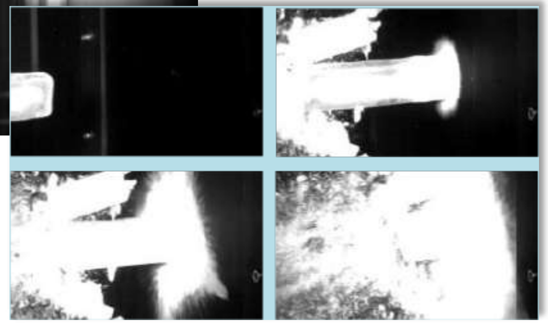
Open Rotor Programme

Blade Release



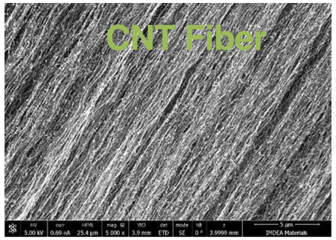
UERF Small Fragment

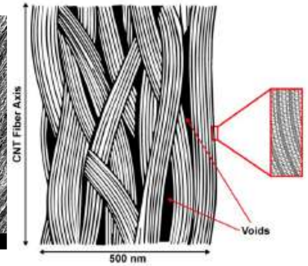
Development of lightweight shield configurations



Ice Impact

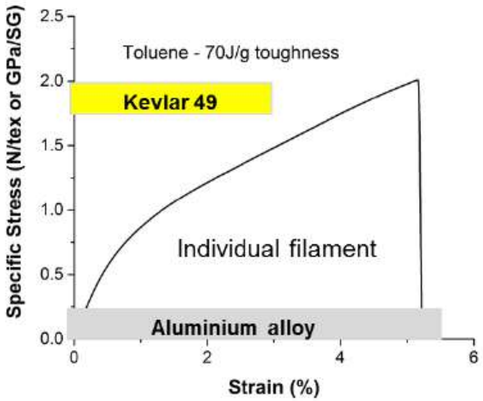
Performance



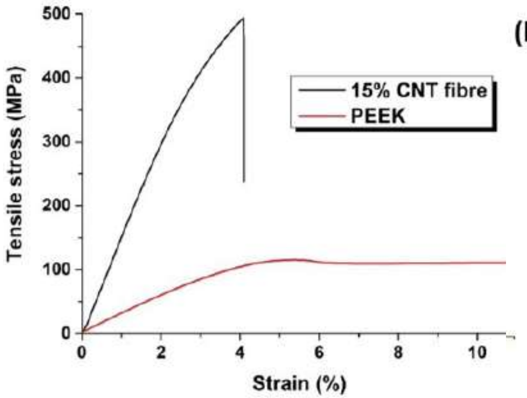


CNT FIBRES AS REINFORCEMENT

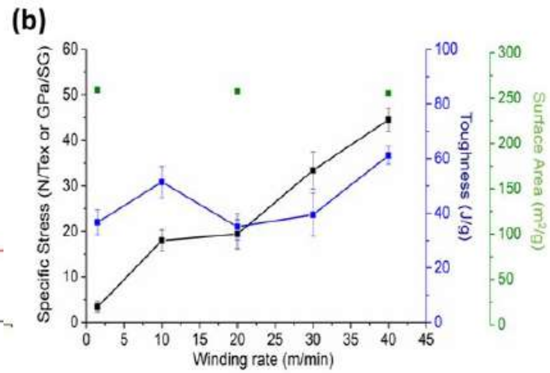
Fibre properties

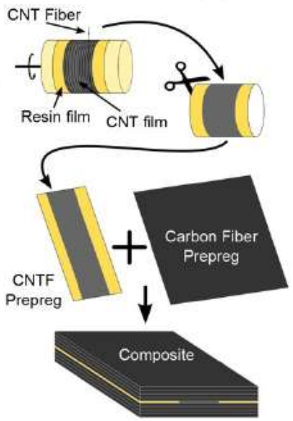


UD composite properties

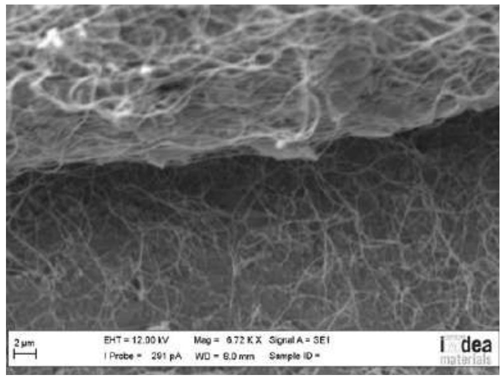


Winding velocity

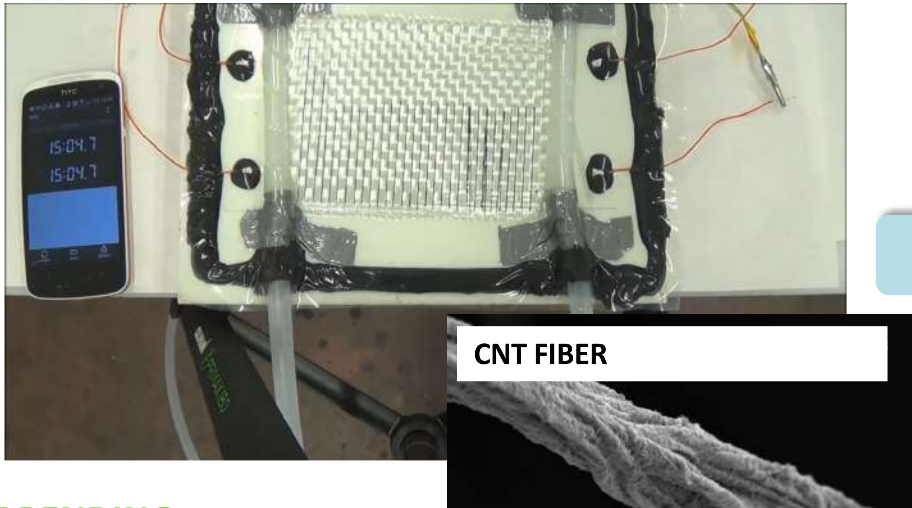




CNT FIBRES FOR LAMINATE INTERLEAVES

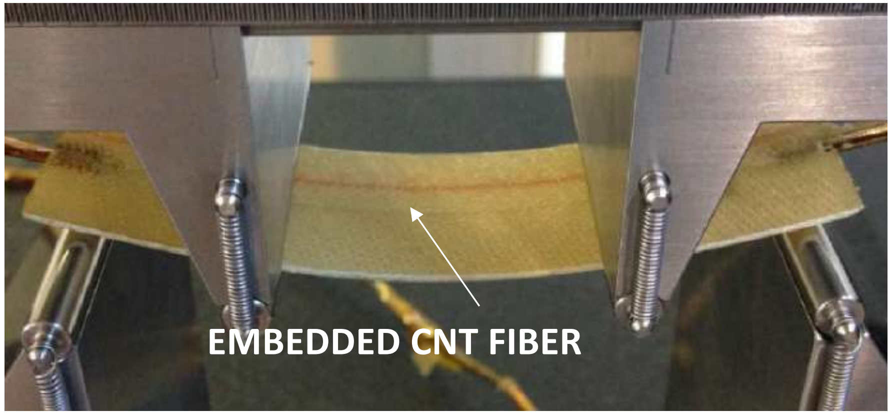


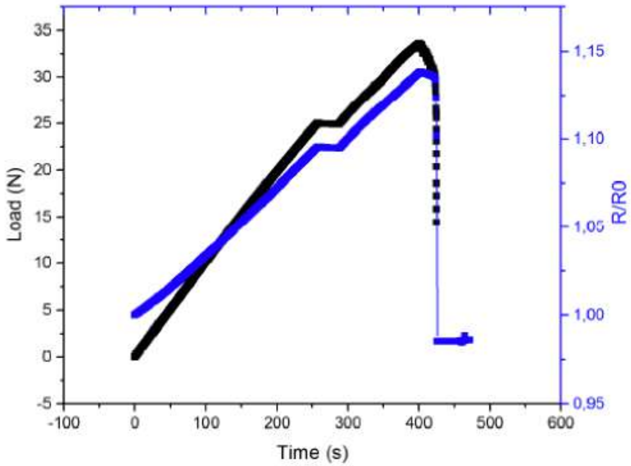
CNT EMBEDDED FIBER AS SENSOR



Performance

FOUR POINT BENDING





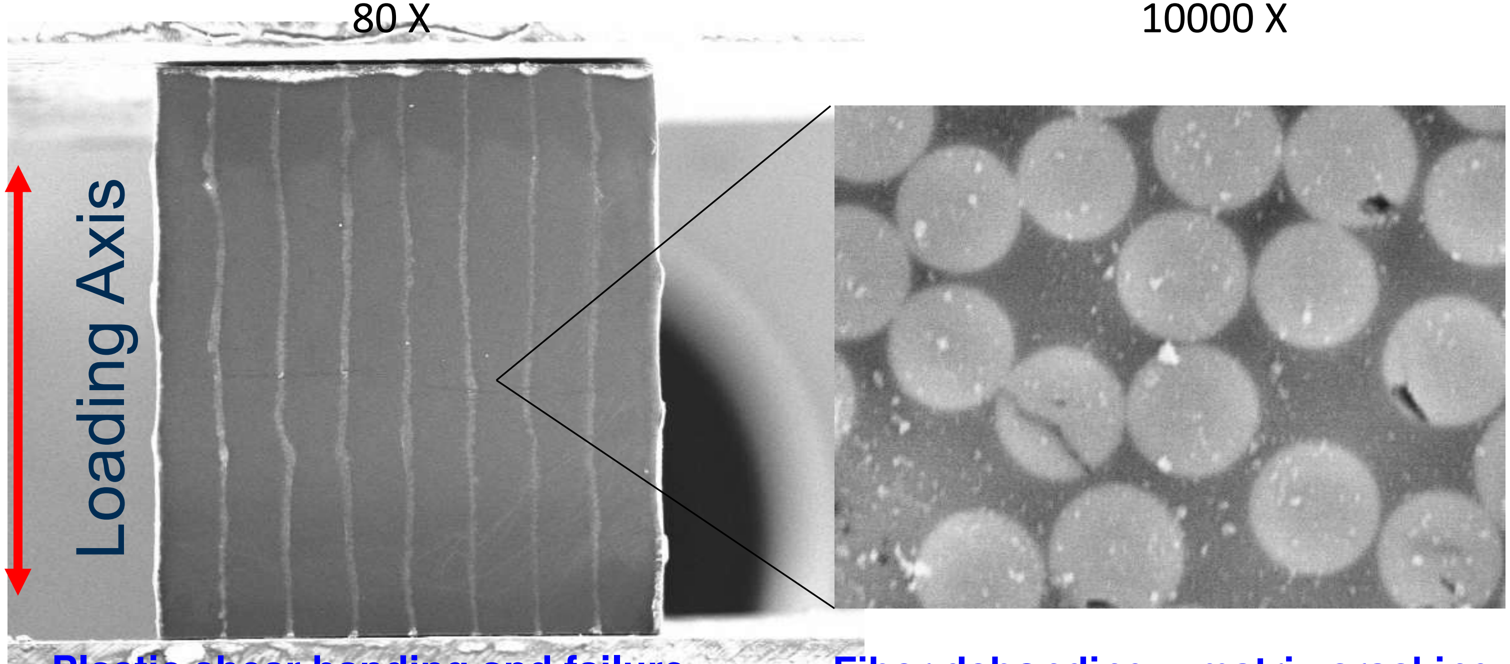
Structure

Micro, Meso and Structural mechanics of composites

EVALUATION OF FAILURE MECHANISMS IN-SITU SEM TESTING

80 X

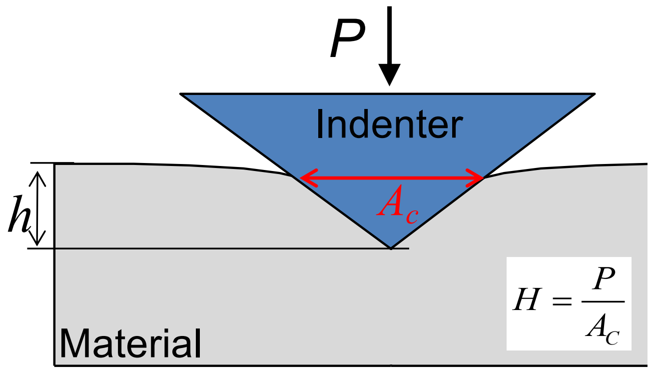
10000 X

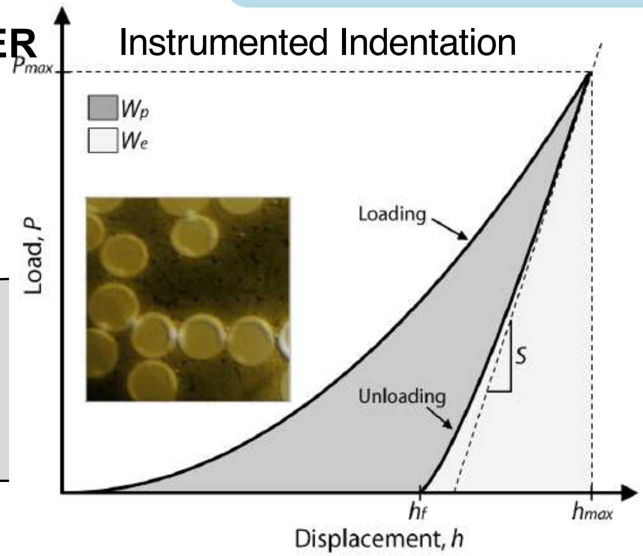


Plastic shear banding and failure ⟵ **Fiber debonding + matrix cracking**

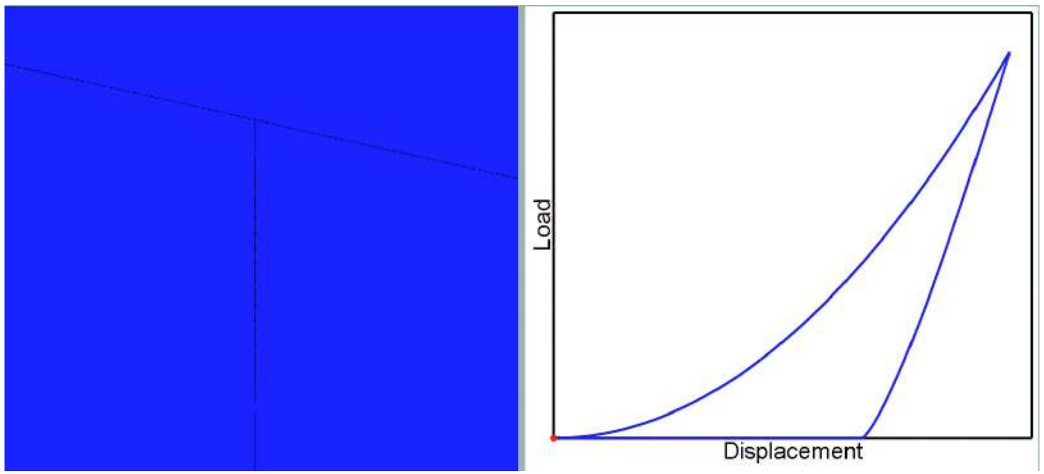
Damage triggered at the microscale

MATRIX CHARACTERIZATION POLYMER MATRIX COMPOSITES

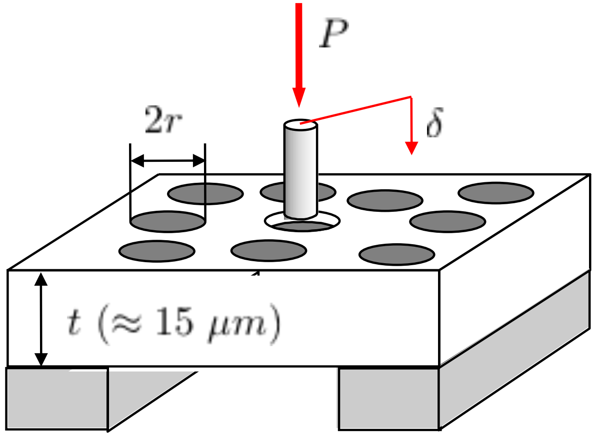


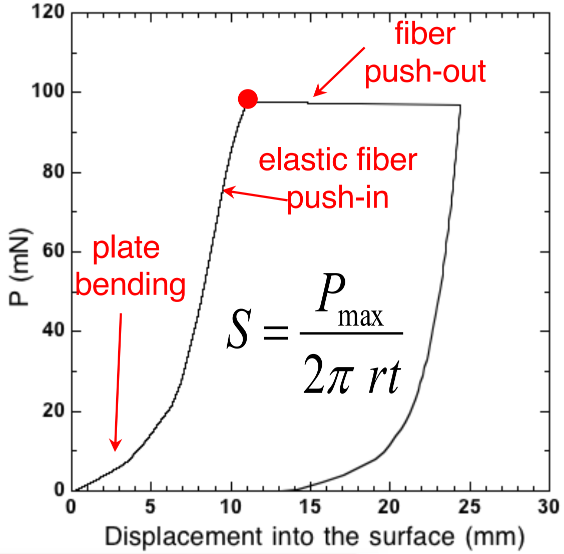


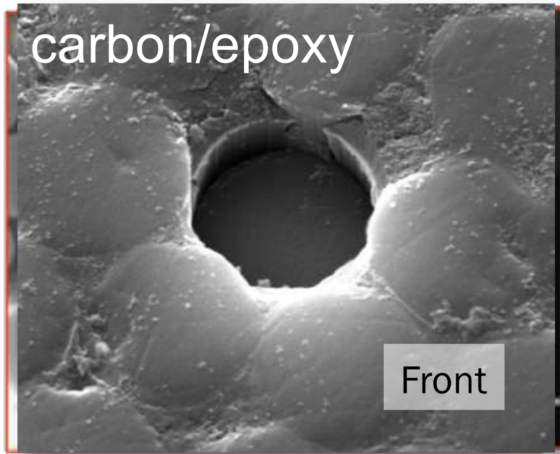
FEM simulation

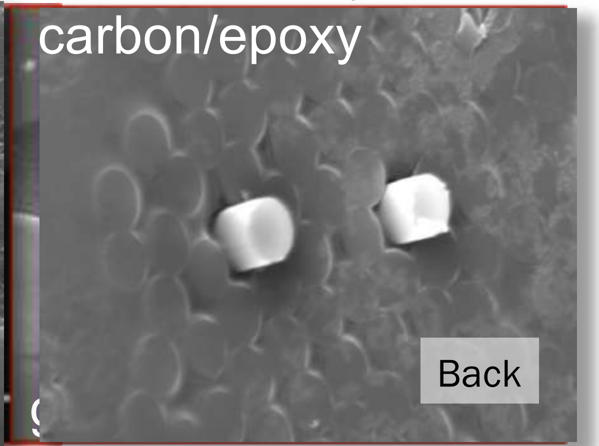


INTERFACE CHARACTERIZATION
POLYMER MATRIX COMPOSITES







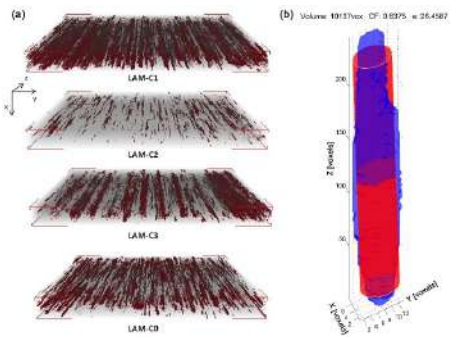


Structure

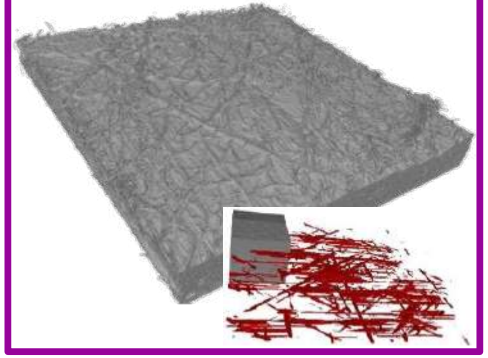
Micro, Meso and Structural mechanics of composites

Processing

Optimization of OoA processing of composites

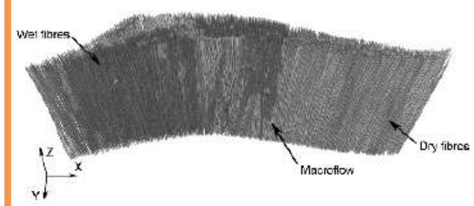


Void evacuation in Out-of-Autoclave Prepregs

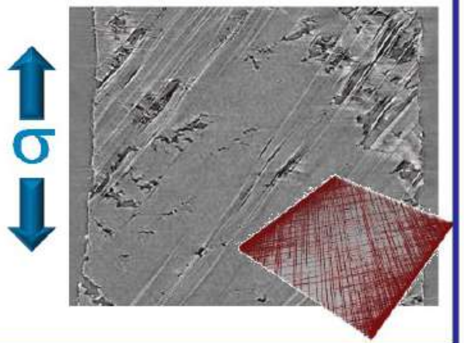


4D tomography

In-situ infiltration – microflow investigation

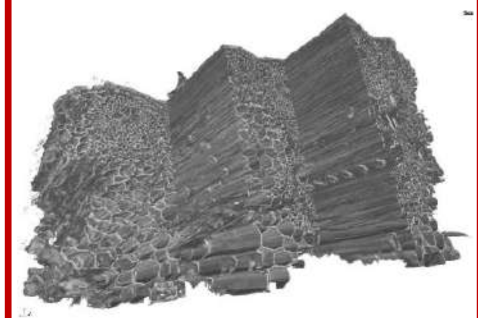


Multiscale XCT for damage evaluation



Damage assessment

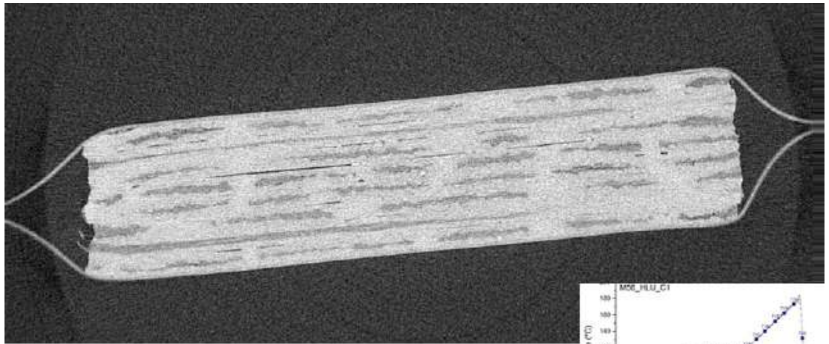
3D microstructure of biomass

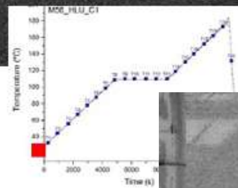


Analysis of impact damage

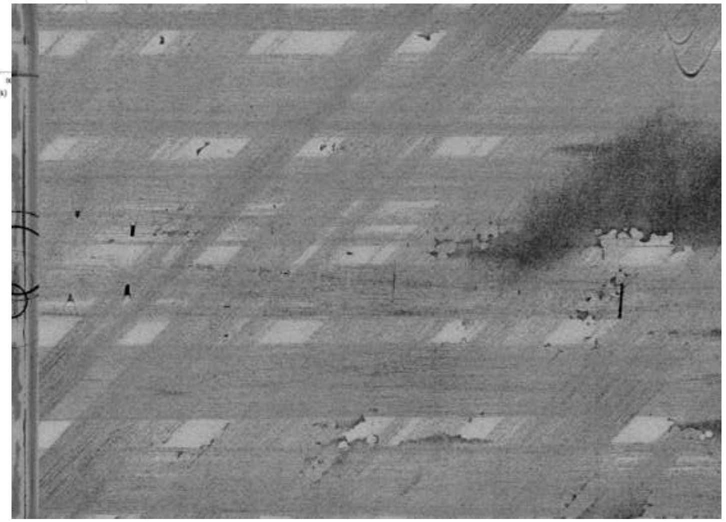
In-situ visualization of void transport in Out-of-Autoclave Prepregs (OoA)

MINI VACUUM BAG $[+45/0/-45/90]_s$



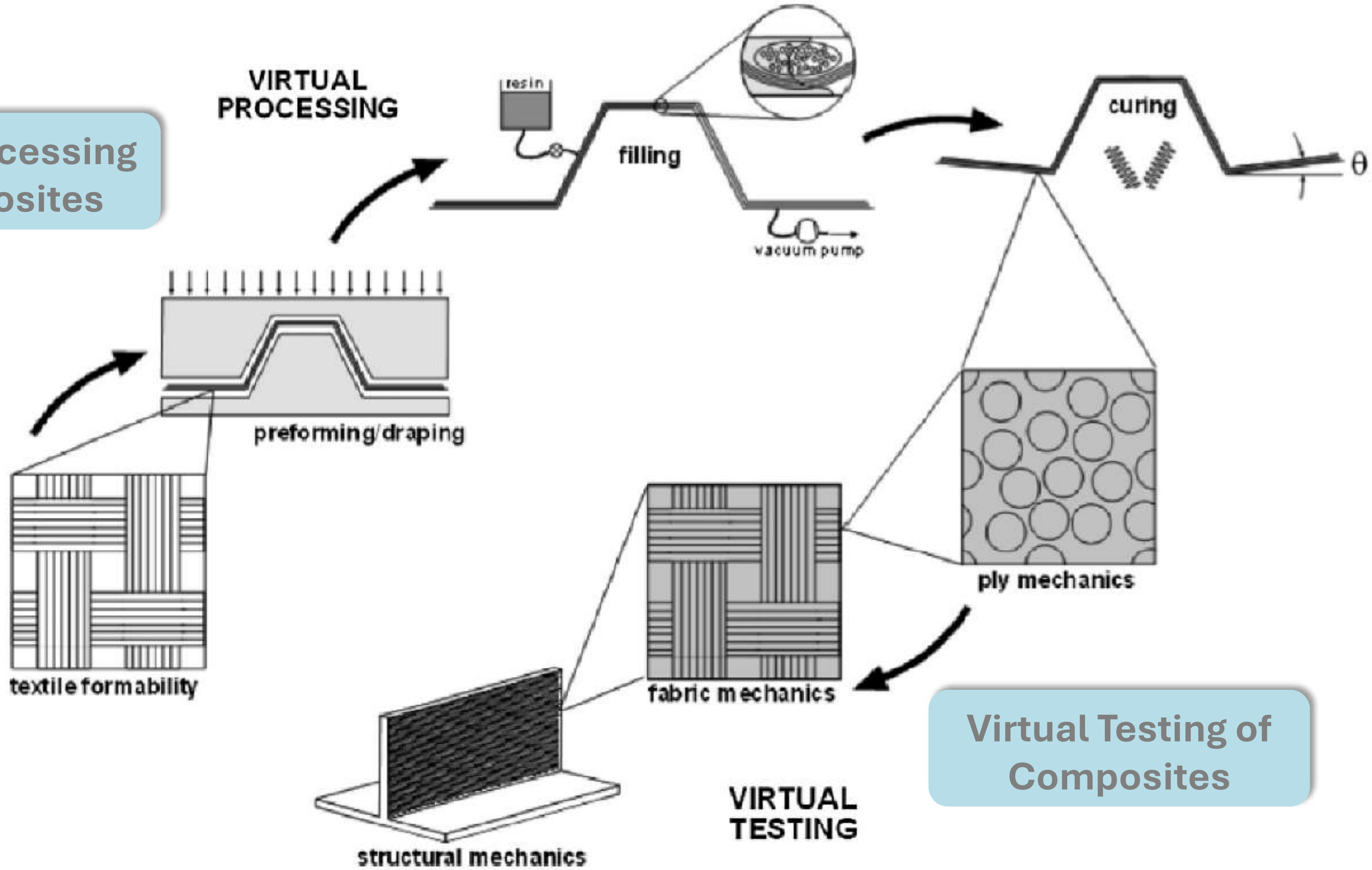


INTERFACE 45/0



Simulation

Virtual Processing of Composites

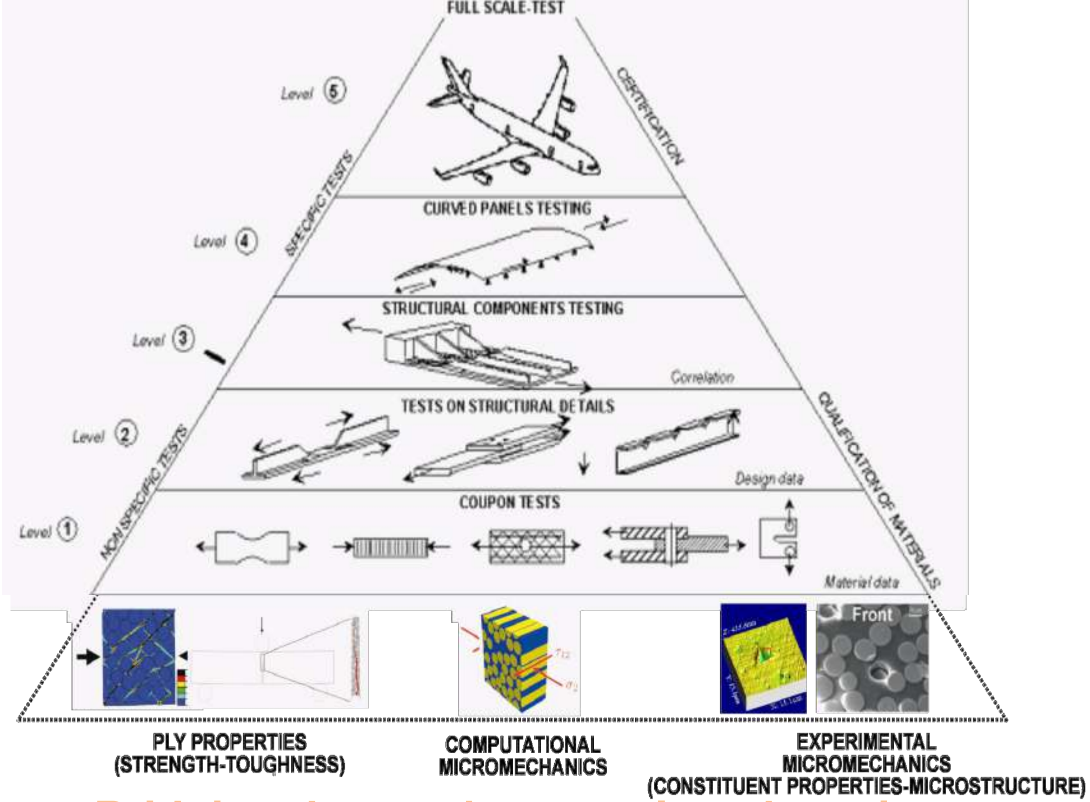


Virtual Testing of Composites

Virtual Testing of Composites

Simulation

TOWARDS A PHYSICALLY BASED MULTISCALE VIRTUAL TESTS

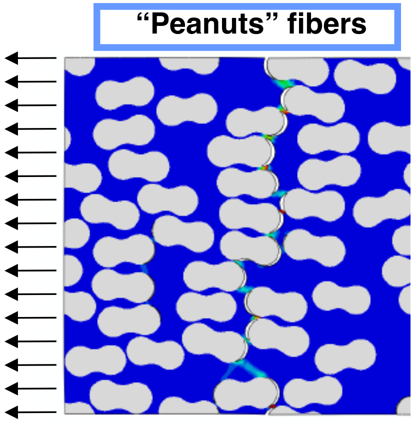


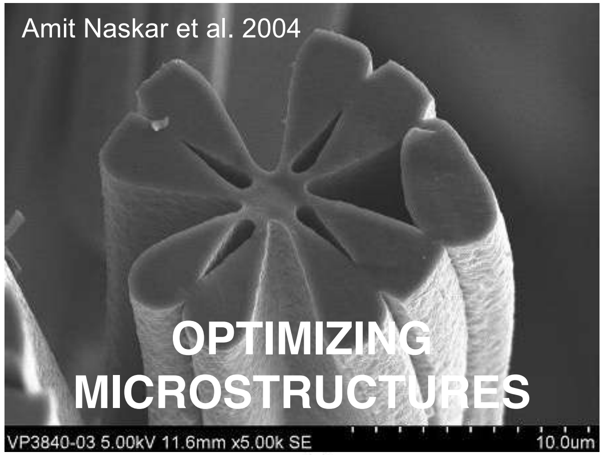
Bridging the gap between length scales

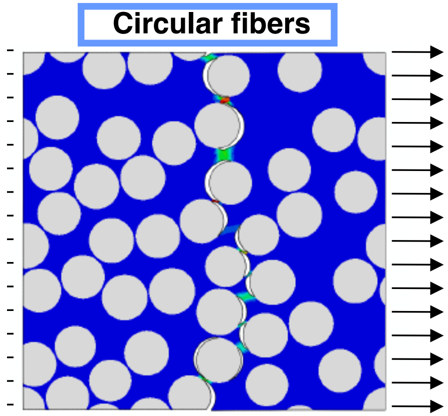
MICROMECHANICS → MESOMECHANICS

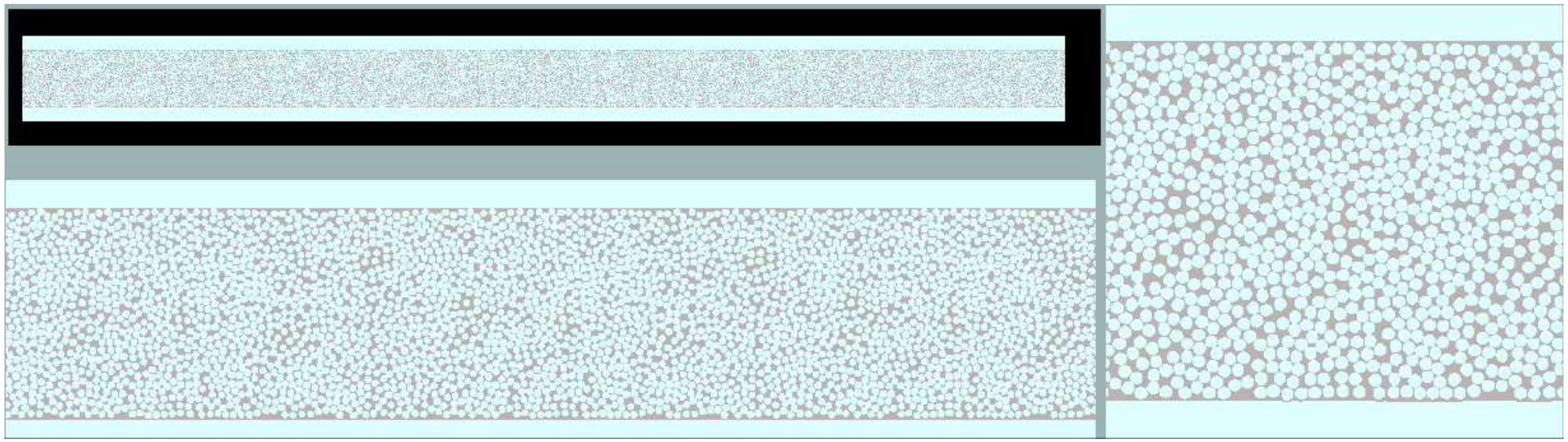
Micromechanics & Material Optimization

Simulation





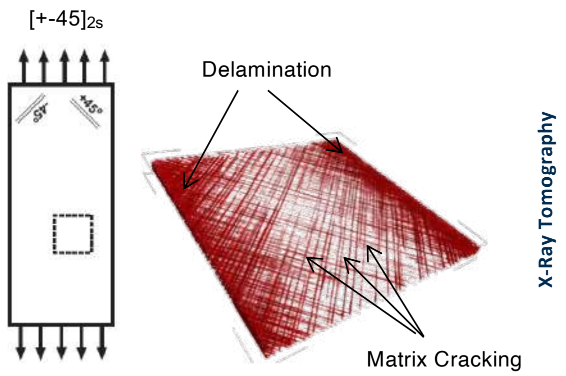




Mesomechanics & Laminate behaviour

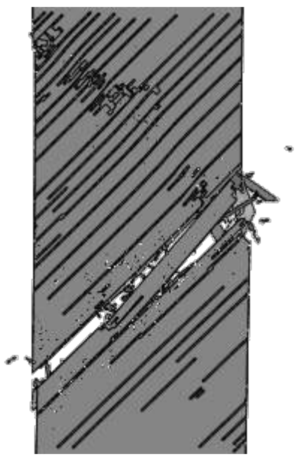
Simulation

In-Plane Shear Test

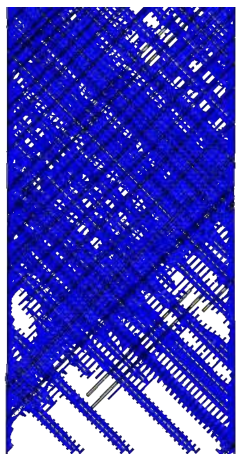


Simulation:

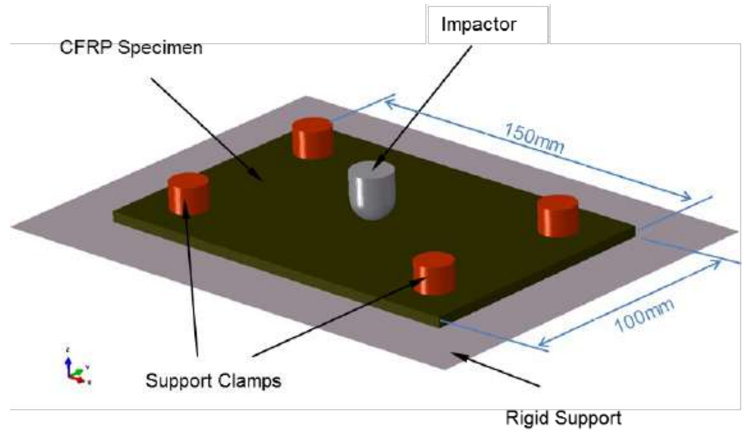
Matrix Cracking

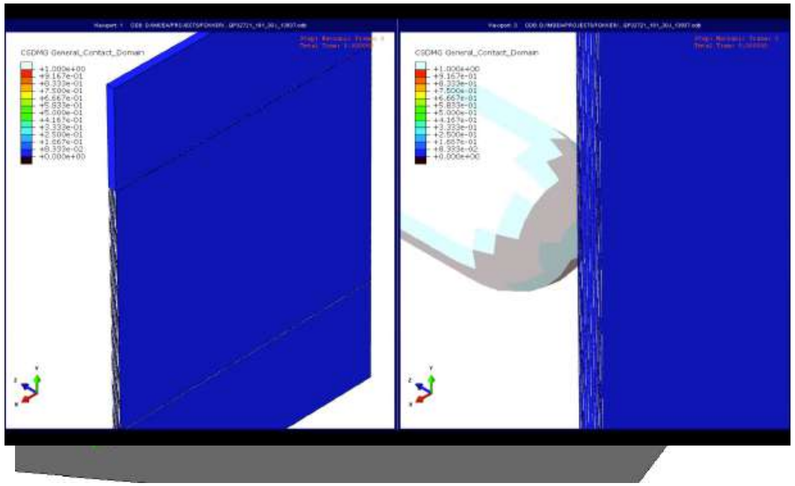


Delamination



Low-Velocity Impact Test

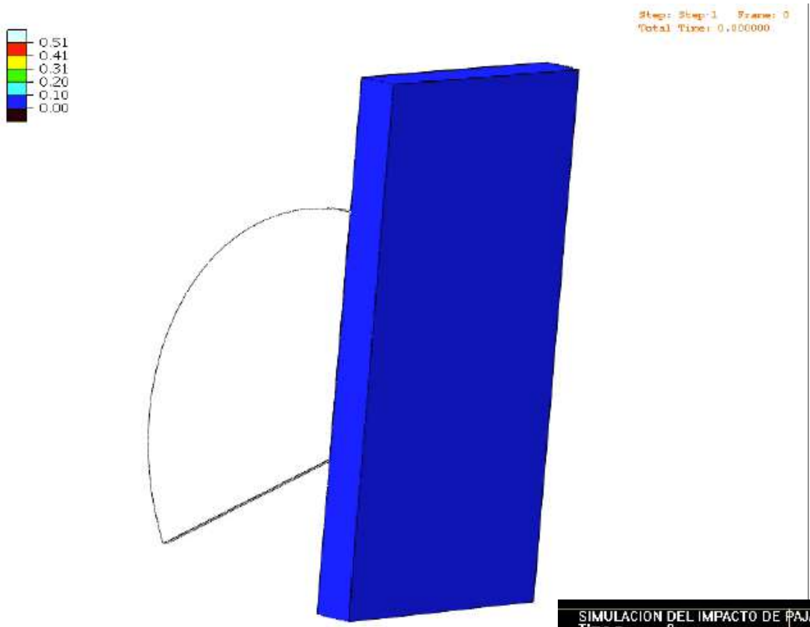




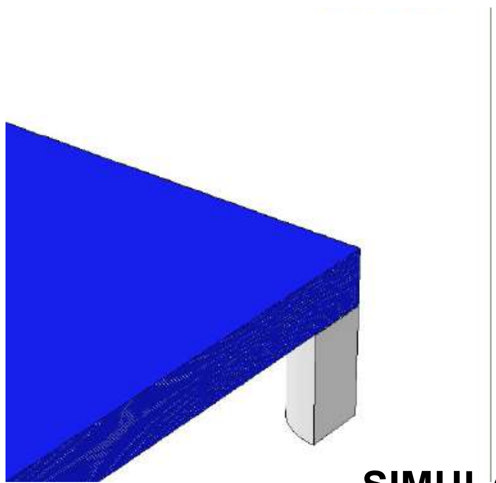
Structural Test

Simulation

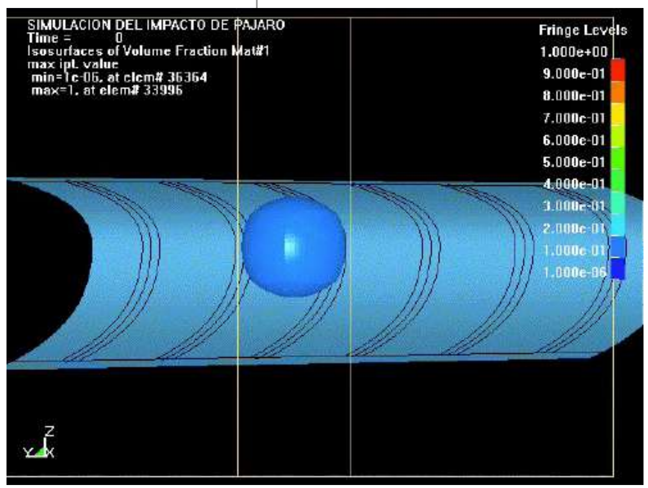
UERF 1/3 Disc



UERF small fra



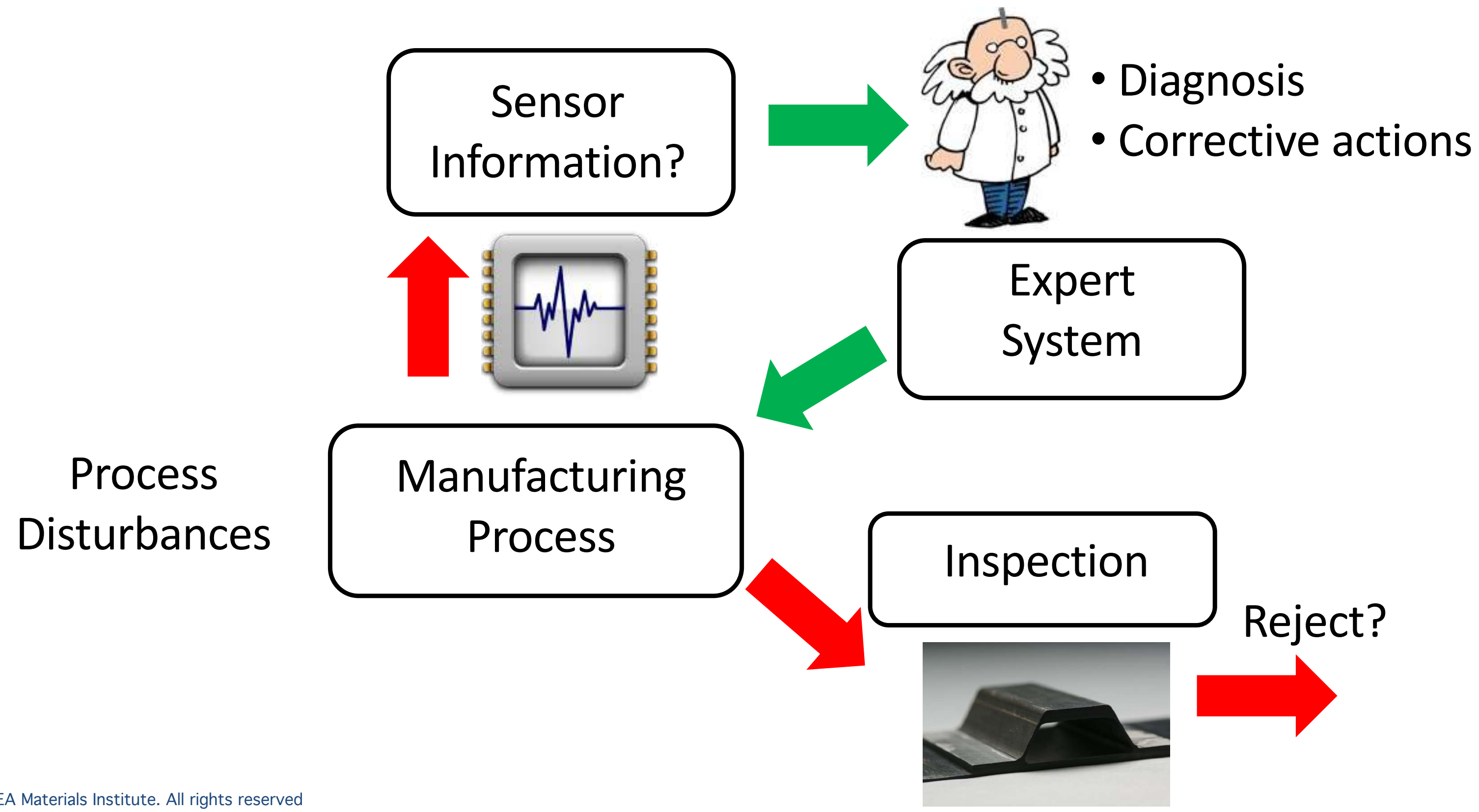
Bird impact



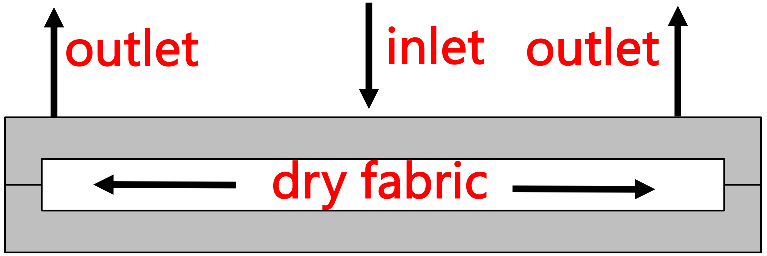
SIMULATION FOR SHIELDING DESIGN

Virtual Processing of Composites

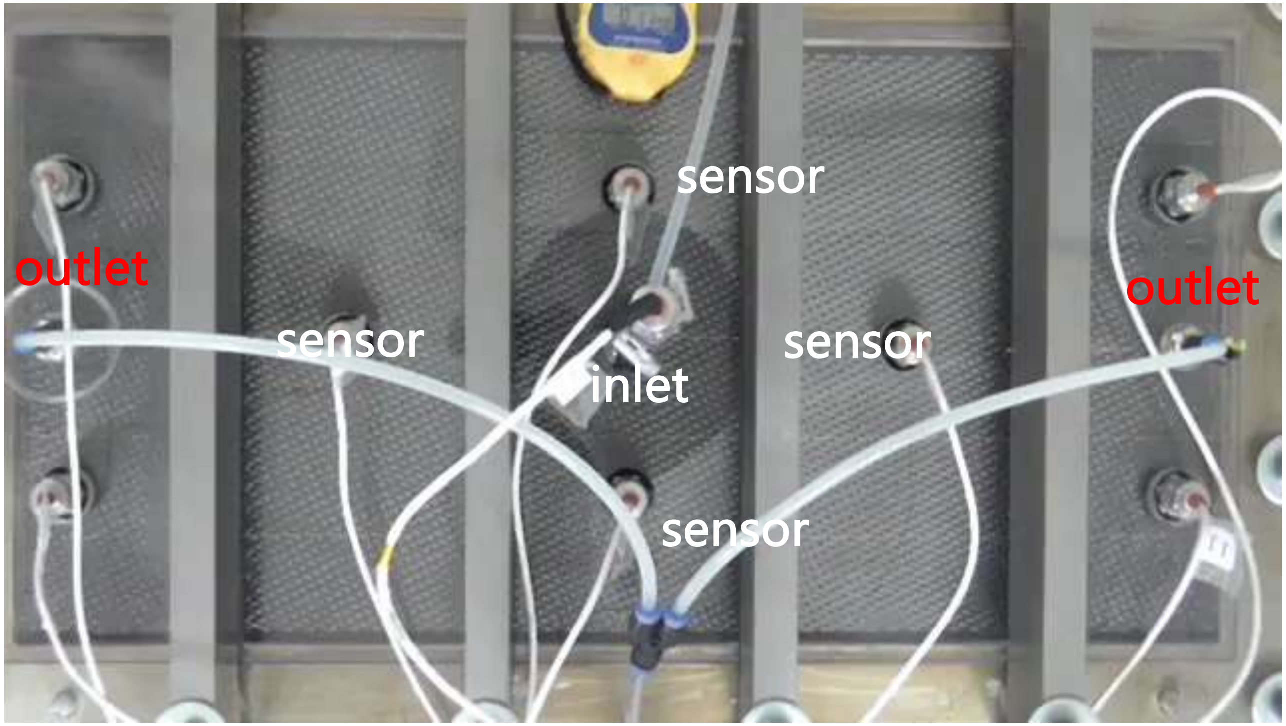
- High cost of processing disturbances (waste materials, inspection, repairing)
- Use sensor information for diagnosis and/or corrective actions.

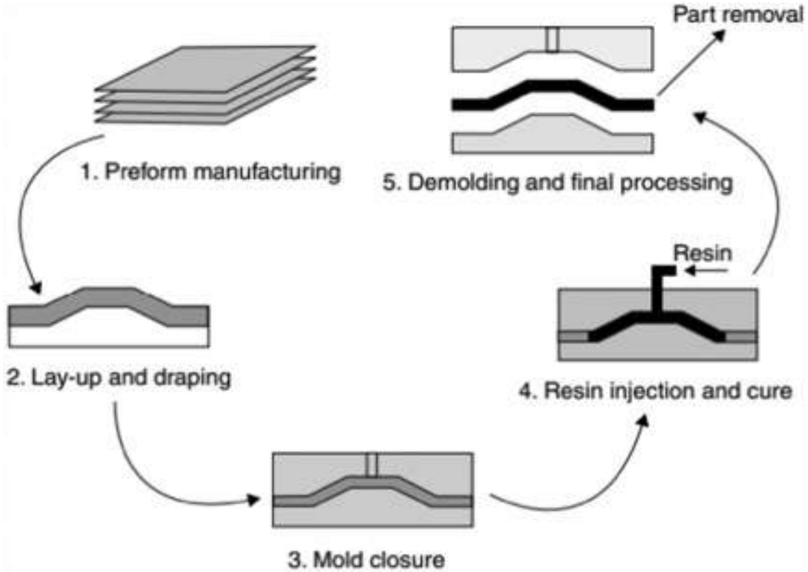


RESIN TRANSFER MOULDING

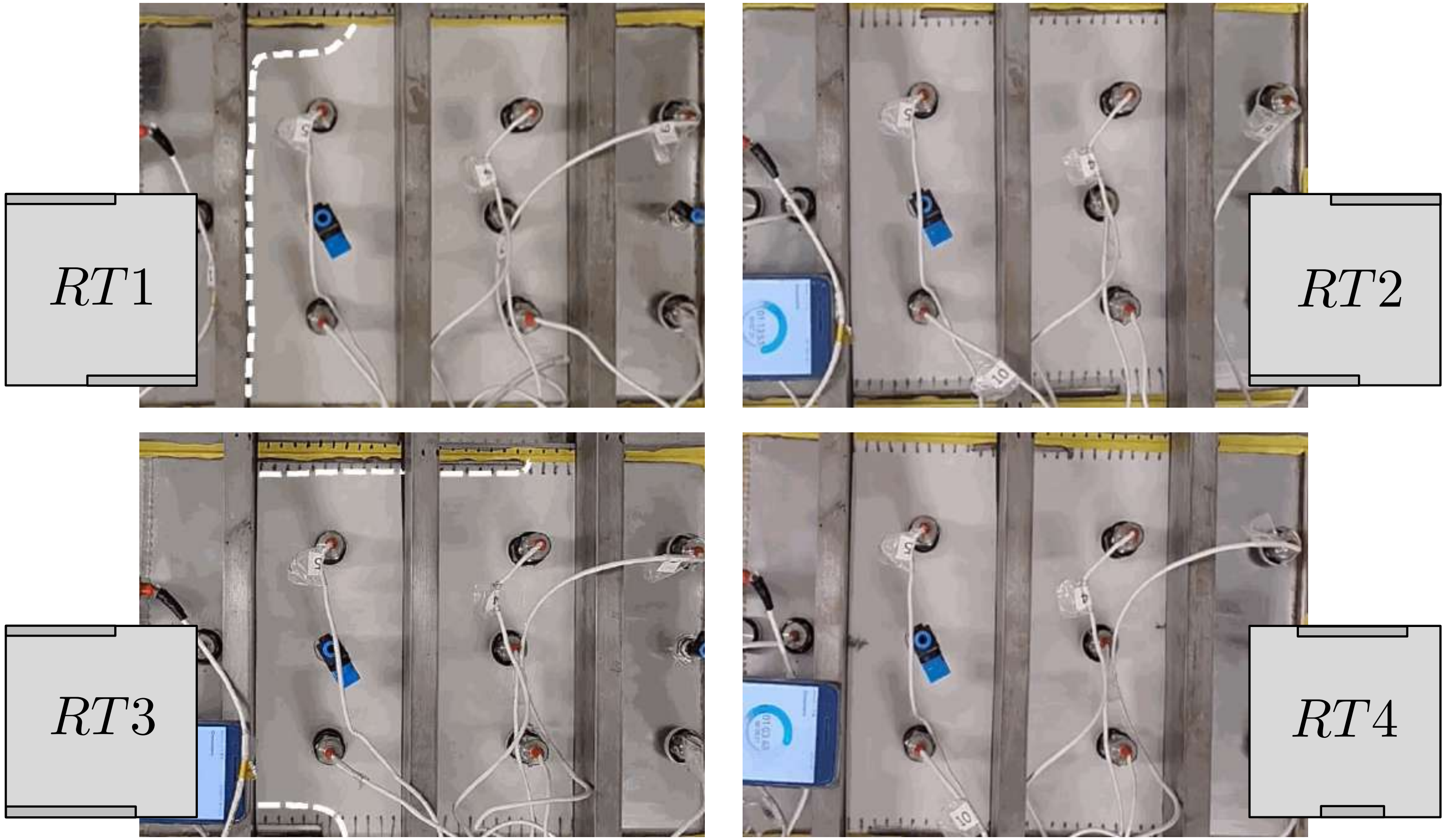


- Low cost as compared with autoclave
- Sensible to void formation

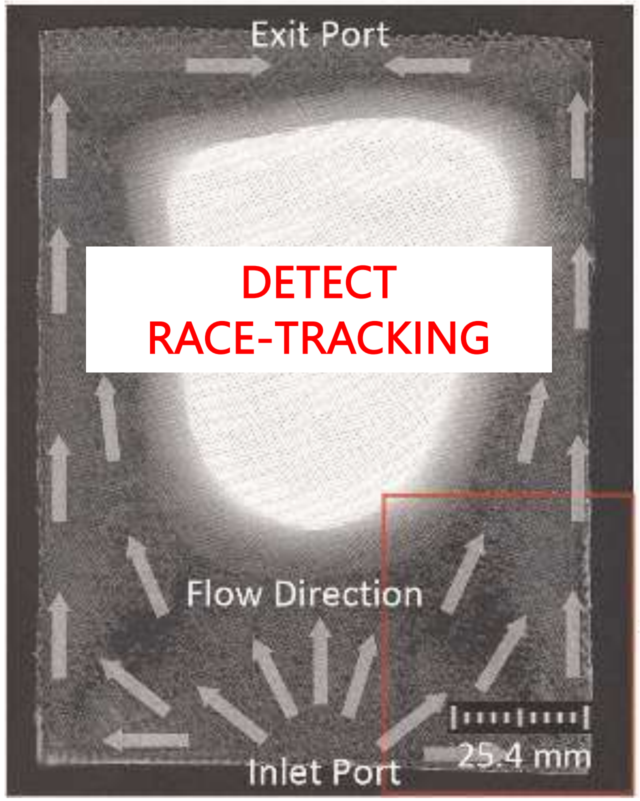




- RTM (Resin Transfer Moulding) is a complex multi-physics problem:
  - Impregnation phase -> porosity & dry spots
  - Curing phase -> lack or excess of cure
  - Residual stresses -> spring-back effects


RT1
RT2
RT3
RT4

- Inhomogeneous flow is responsable of dry-spot formation (race-tracking)

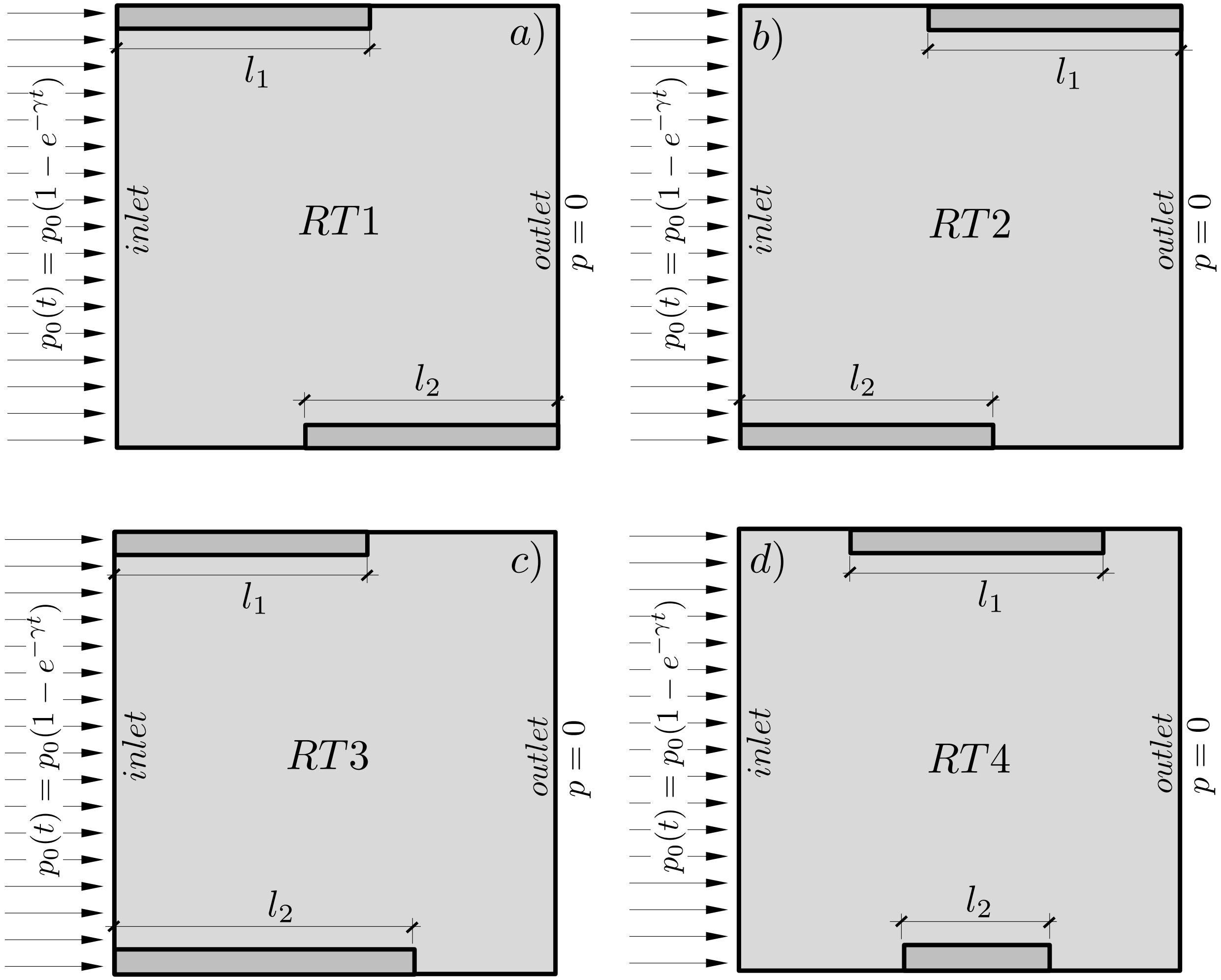


- Regions with low velocity produce larger voids (outlet)

Hamidi & Altan, Intern. Polymer Processing, 32, 2017

FluidAI

SIMULATE FAST

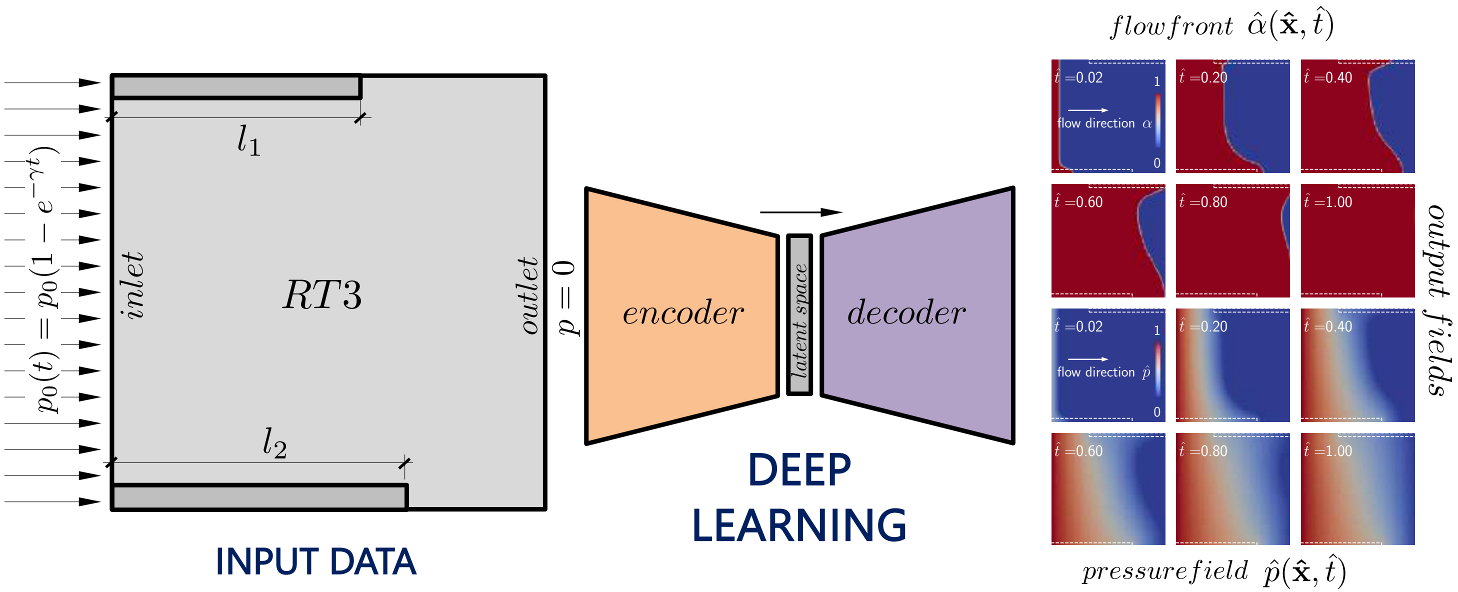


Virtual Processing

- OpenFoam (CFD)
- Pressure field
- Flow evolution

FluidAI

SIMULATE FAST



INPUT DATA
RT length, position, strength

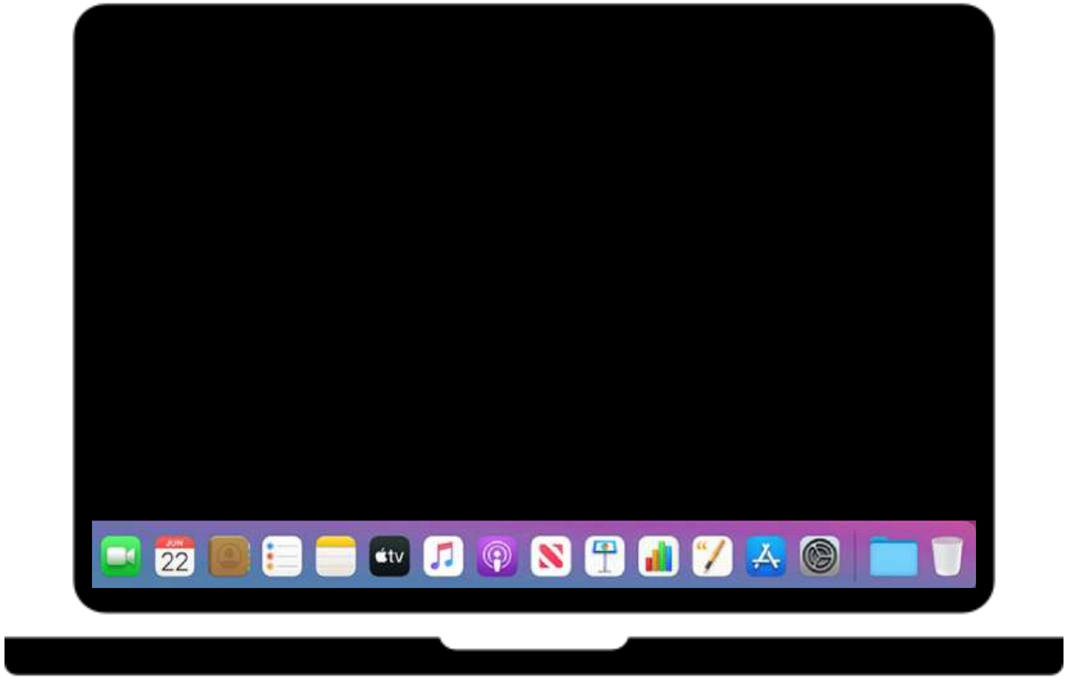
SYNTHETIC FIELDS
Pressure, Flow Evolution

A deep encoder-decoder for surrogate modelling of liquid moulding of composites, EAAI, 2023

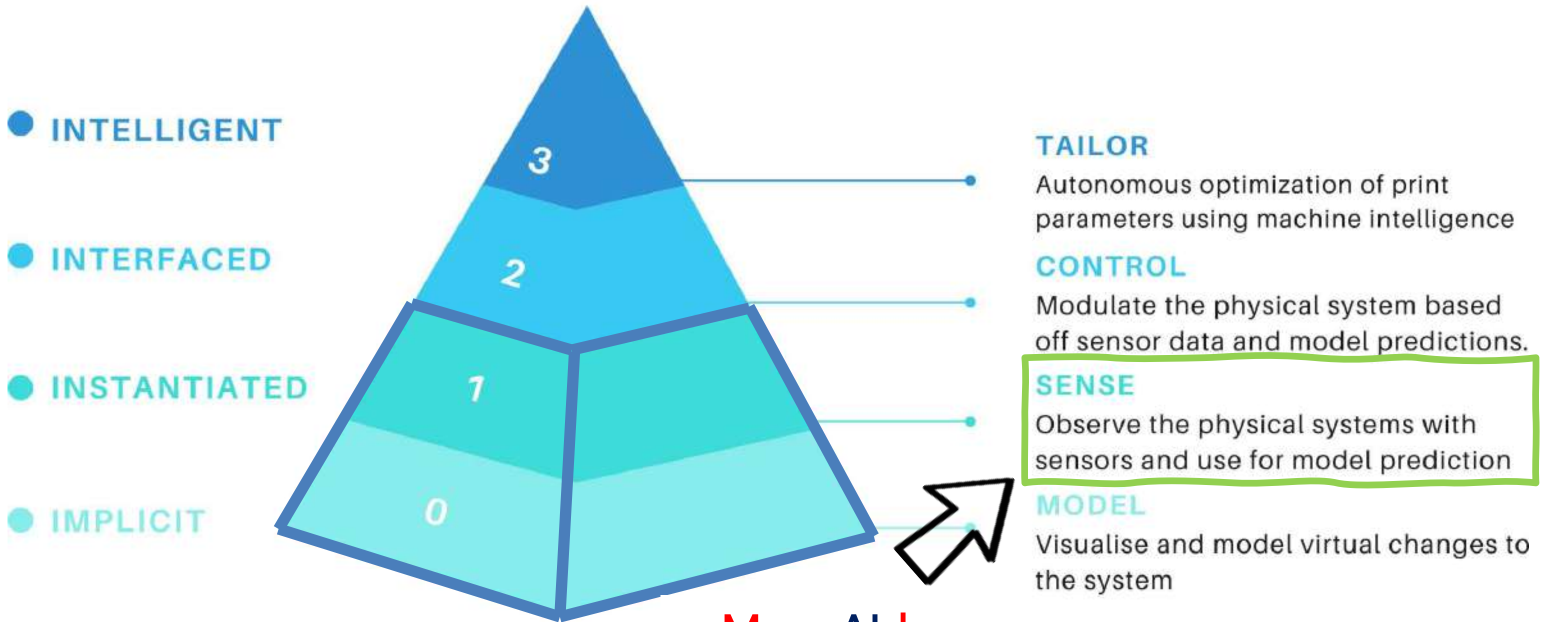
FluidAI

SIMULATE FAST

- Enable cloud calculations
- Thousand of simulations without computational cost
- Bridging Virtual Processing close to the end-user



THE DIGITAL TWIN PYRAMID (Phua *et al.*, 2022)

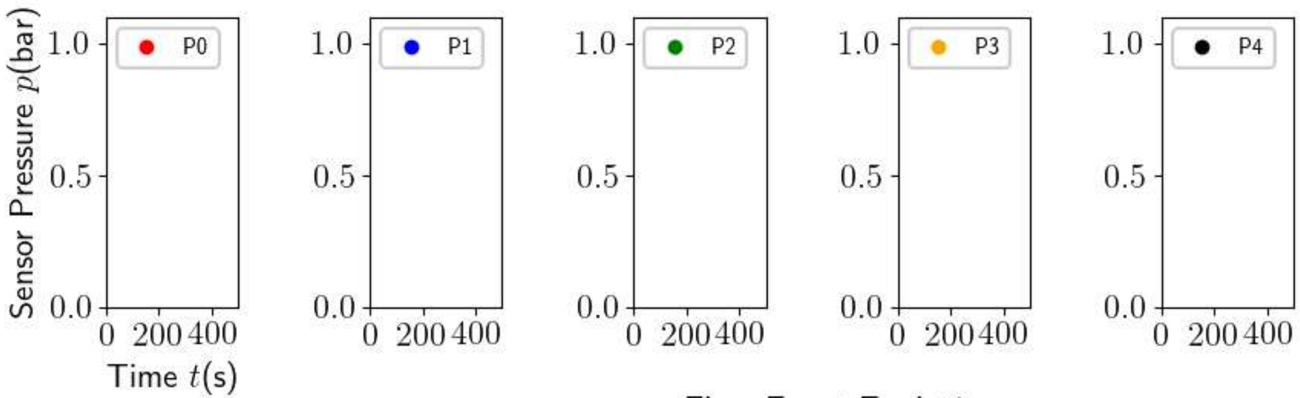


ManuAId

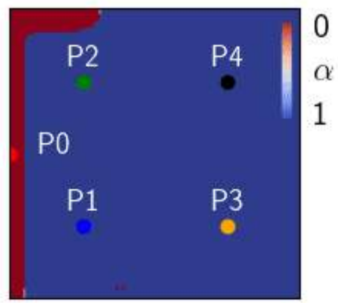
ENABLE DIGITAL TWINS

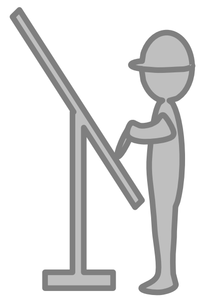
UNIT OF EXCELLENCE MARÍA DE MAEZTU

DIGITAL TWINS

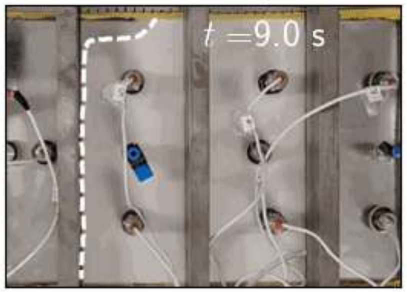


Flow Front Evolution

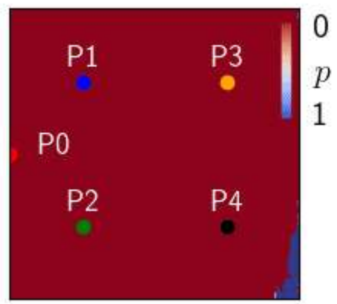




Ground Truth Experiment



Pressure field evolution

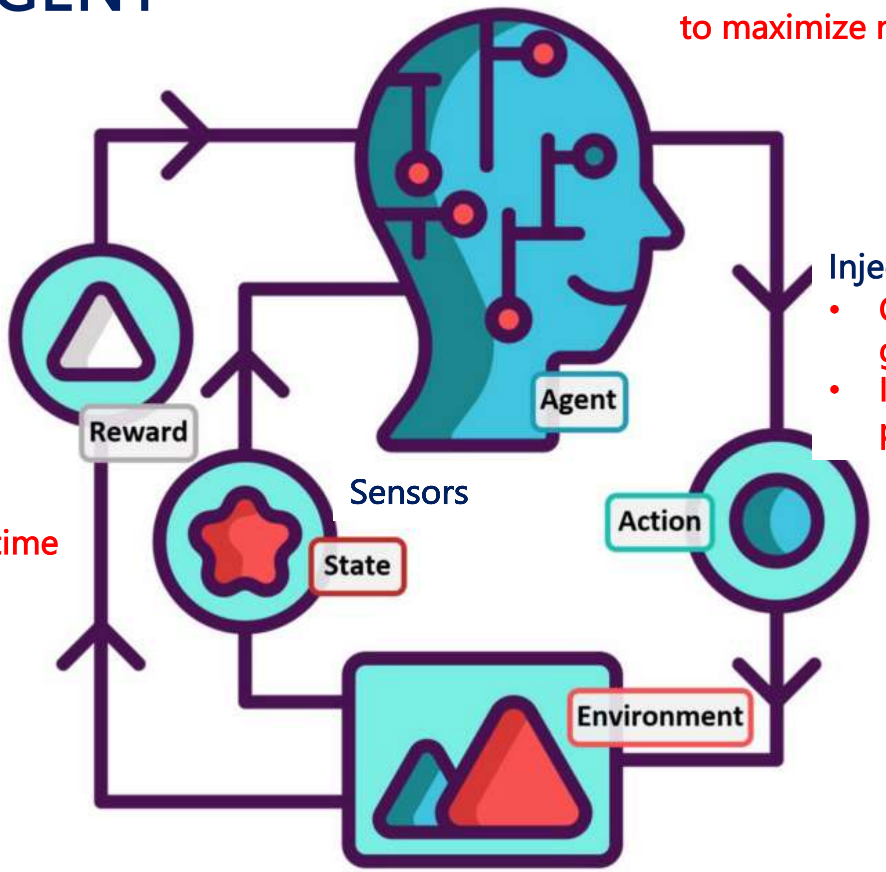


SMART
AGENT

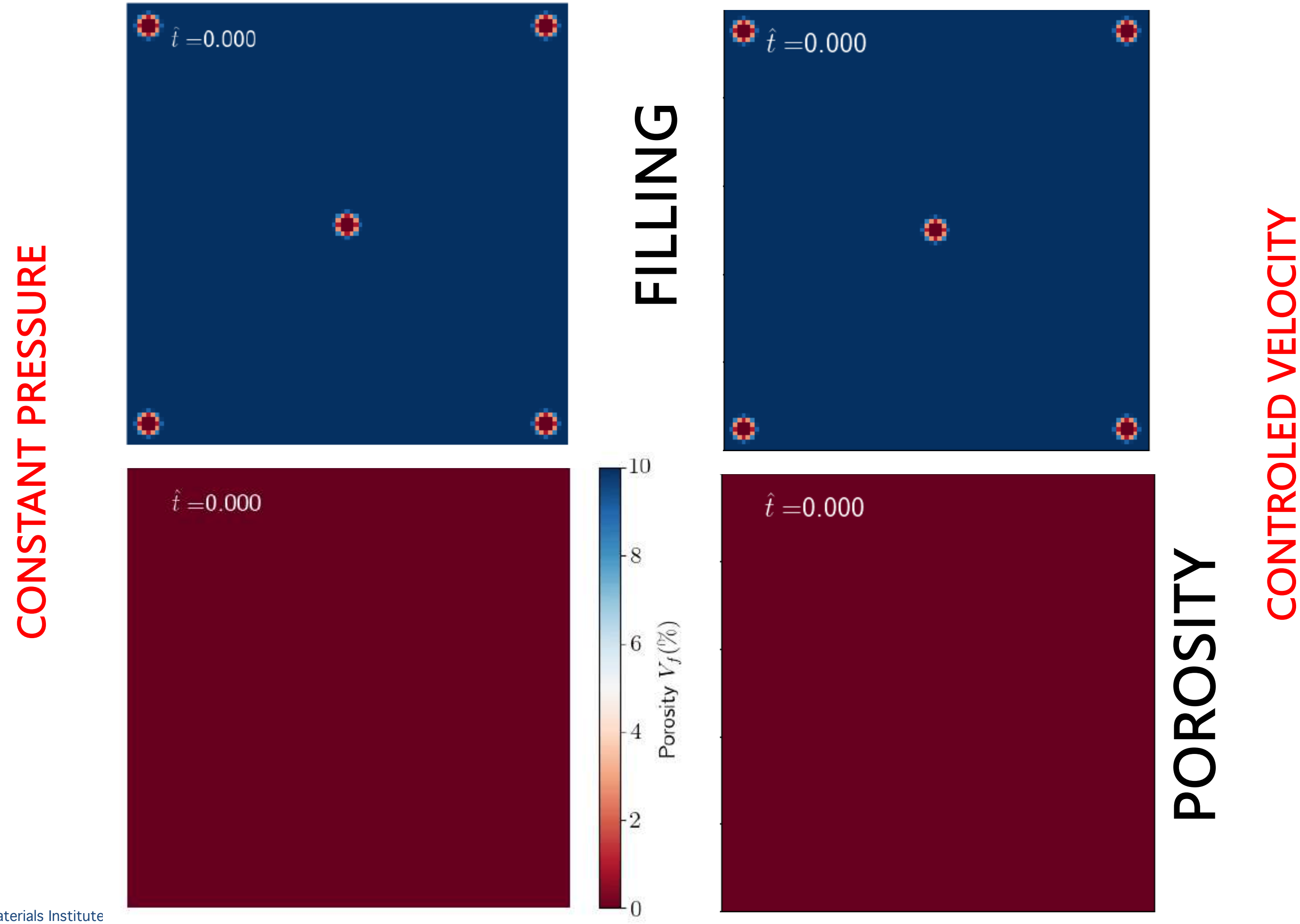
Neural Network:
- Record the best injection steps to maximize reward

Injection decisions:
- Opening/closing gates
- Increasing/decreasing pressure

Optimize:
- Lower porosity
- Lower injection time



MANUFACTURING SYSTEM


CONSTANT PRESSURE
FILLING
CONTROLED VELOCITY
POROSITY
$\hat{t}$ =0.000
Porosity $V_f(\%)$
10
8
6
4
2
0

THANKS !!

www.materials.imdea.org