

**NCC-L**

NATIONAL  
COMPOSITE CENTRE  
LUXEMBOURG

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY

**LIST** 

# POLYMER PROCESSING SEMINAR

DISCOVER HOW WE CAN HELP YOU IMPROVE  
YOUR PRODUCTION PROCESS

11 JANUARY 2018 FROM 10 A.M. TO 1:30 P.M.

**Dr. Vincent Berthé**  
*Senior research and technology associate*  
**LIST, NCC-L - Polymer Processing**  
*vincent.berthe@list.lu*



**ENVIRONMENTAL  
RESEARCH AND  
INNOVATION (ERIN)**

- Water security and safety
- Plant Science and biotechnologies
- Life cycle sustainability and risk assessment
- Analysis and visualization of environmental scientific data

**MATERIALS  
RESEARCH AND  
TECHNOLOGY (MRT)**

- Nanomaterials and nanotechnologies
- Composite materials

**IT FOR  
INNOVATIVE SERVICES  
(ITIS)**

- Decisional knowledge dynamics
- Trusted service systems
- Service engineering with impact

**NCC-L**

NATIONAL  
COMPOSITE CENTRE  
LUXEMBOURG

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY

**LIST**



# LIST AT A GLANCE

## RESEARCH & TECHNOLOGY ORGANIZATION (RTO)

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



### LIST's main figures

- A budget of approximately **EUR 64 million\***
- Contract research: **EUR 10.5 million\***
- Competitive research: **EUR 14.5 million\***
- **630** employees, 3% of whom are researchers
- About **70** PhD students
- Nearly **forty** different nationalities represented
- **350** scientific publications referenced
- A portfolio of **50** patent families

The expertise of LIST's researchers is deployed in close to **300** research projects, **30%** of which are conducted within European programmes.

\* 2015 Objectives of the Performance Contract signed with the Luxembourg State for 2015-2017

APPLYING RESEARCH WHERE  
RESEARCH IS NEEDED

POSITIONING LUXEMBOURG  
AS A SMART NATION

TRANSFERRING NEW  
TECHNOLOGIES TO INDUSTRY

ACCELERATING THE DEVELOPMENT  
OF NEW TECHNOLOGIES

PROVIDING EXPERTISE  
TO NATIONAL POLICY MAKERS

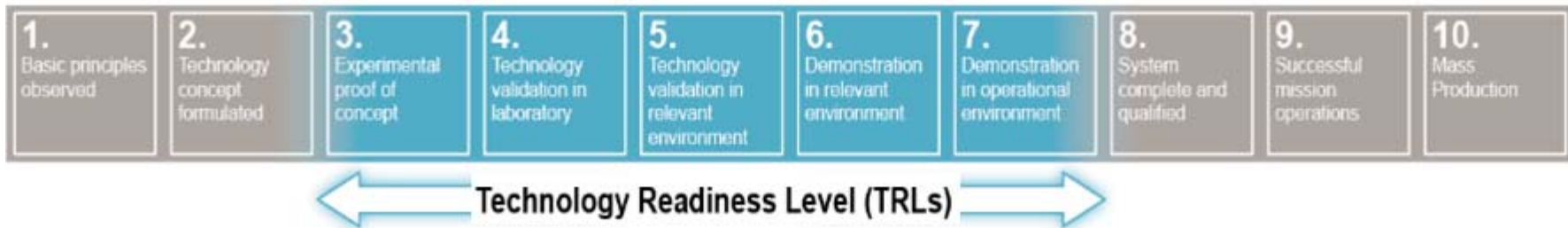
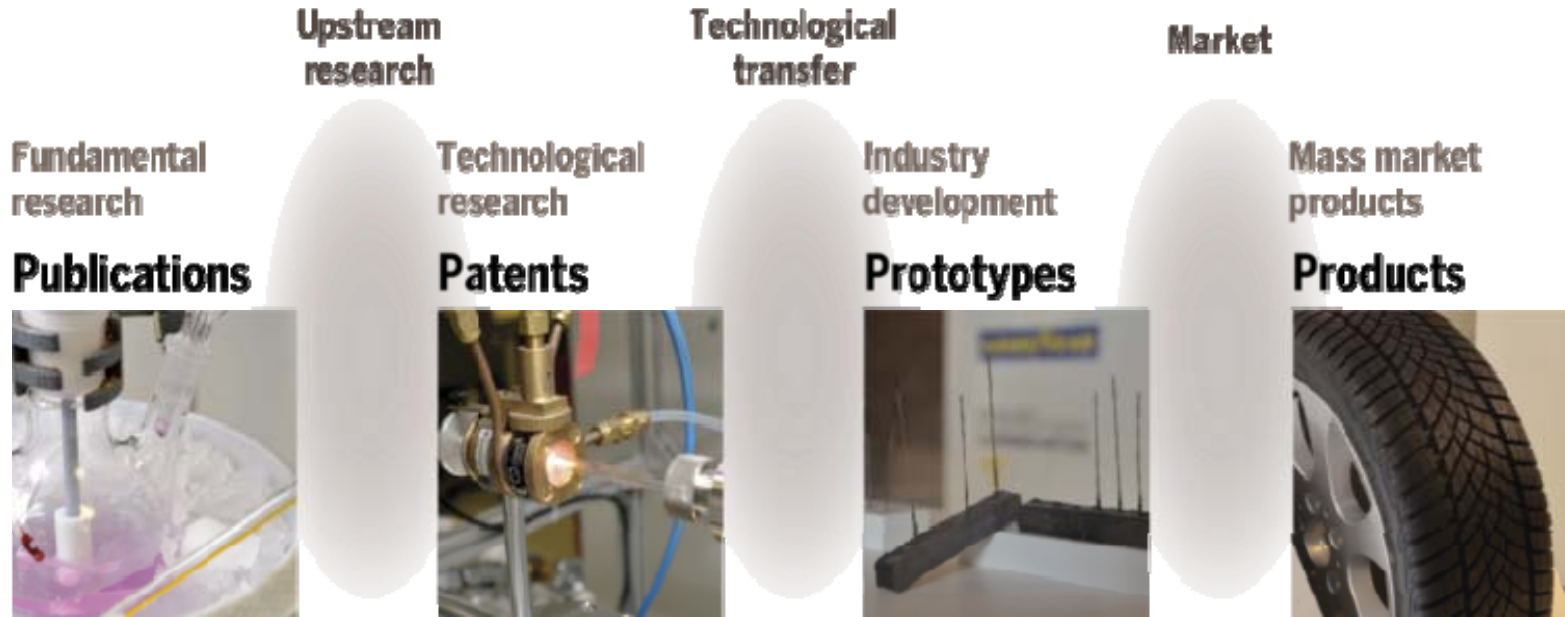
STRENGTHENING THE NATIONAL  
RESEARCH AND INNOVATION COMMUNITY



# LIST'S MISSION & POSITIONING

## SUPPORTING INDUSTRY INNOVATION

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



# MATERIAL R&D IN LUXEMBOURG

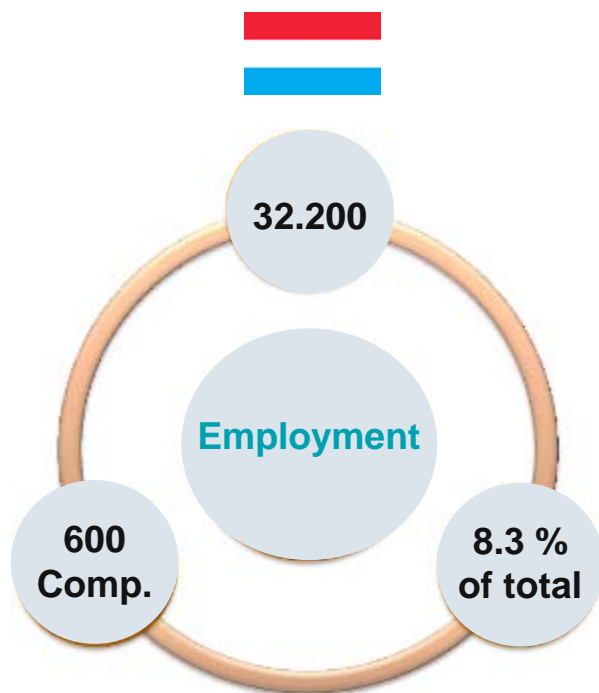
## EU, LUX & LIST STRATEGY

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



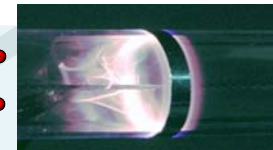
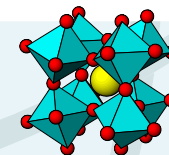
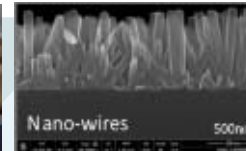
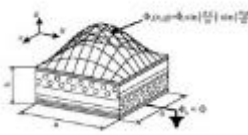
**Advanced Materials** are one of 6 Key Enabling Technologies (KETs)

*“70% of product-innovation is based on new / improved properties **materials**”*



Source Luxinnovation

- **Historic & largest** industry sector in Luxembourg  
\_ composites, glass industry, sensors, metallurgy \_
- Key in Luxembourg’s diversification **strategy** and driver of **competitiveness**
- Impact on various sectors  
\_ automotive, space, building, engineering, electronics ...





# R&D IN LUXEMBOURG

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



INSTITUT LUXEMBOURGEOIS DE REGULATION



LE GOUVERNEMENT  
DU GRAND-DUCHÉ DE LUXEMBOURG  
Ministère de l'Agriculture,  
de la Viticulture et de la  
Protection des consommateurs



LE GOUVERNEMENT  
DU GRAND-DUCHÉ DE LUXEMBOURG  
Ministère de l'Économie



LE GOUVERNEMENT  
DU GRAND-DUCHÉ DE LUXEMBOURG  
Ministère du Développement durable  
et des Infrastructures

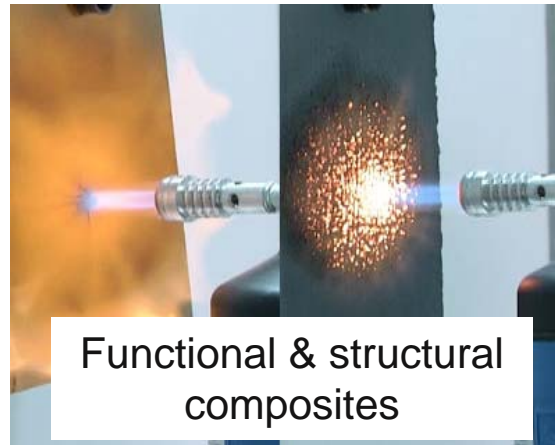
# MATERIALS R&T DEPARTMENT

## MAIN FIELDS OF R&D ACTIVITIES

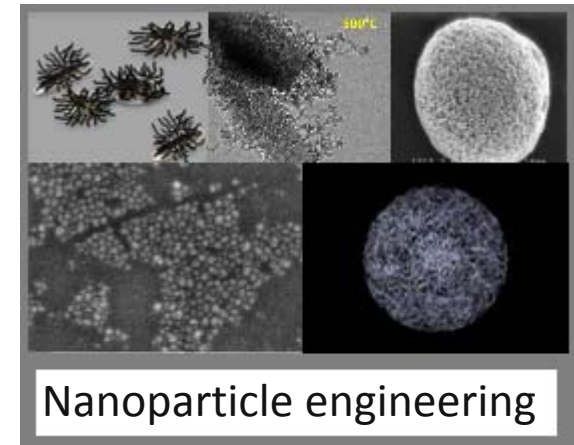
LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



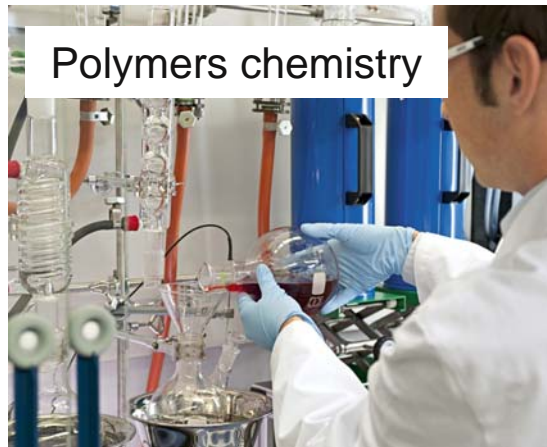
Polymer & Composite processing



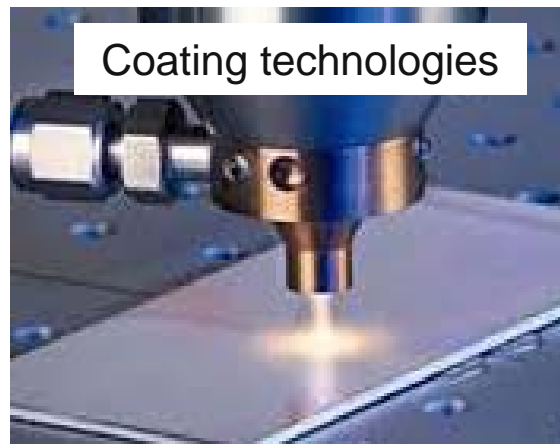
Functional & structural composites



Nanoparticle engineering



Polymers chemistry



Coating technologies

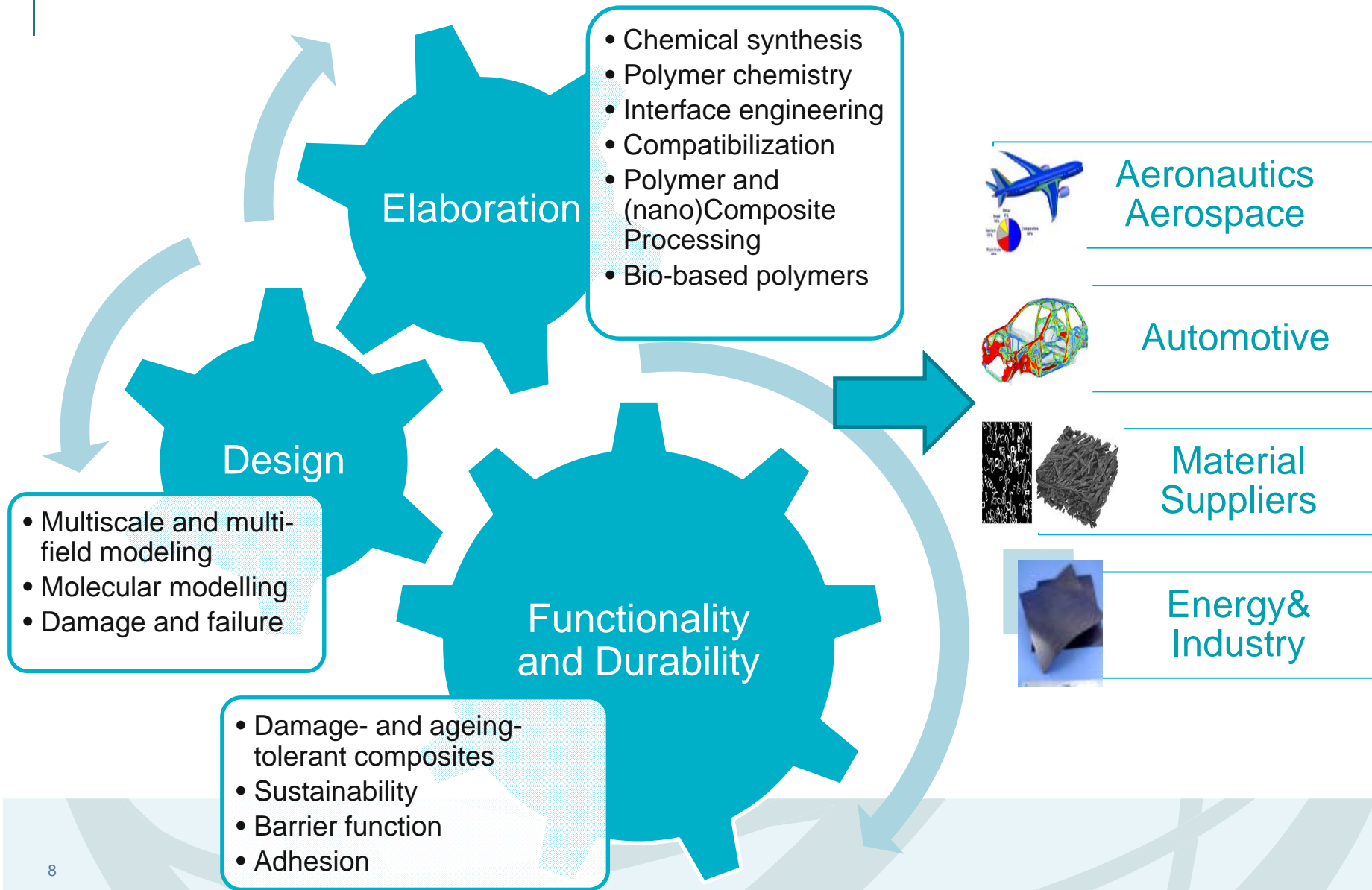


Characterization

# MATERIALS R&T DEPARTMENT

## SUSMAT UNIT – KEY ACTIVITIES

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY

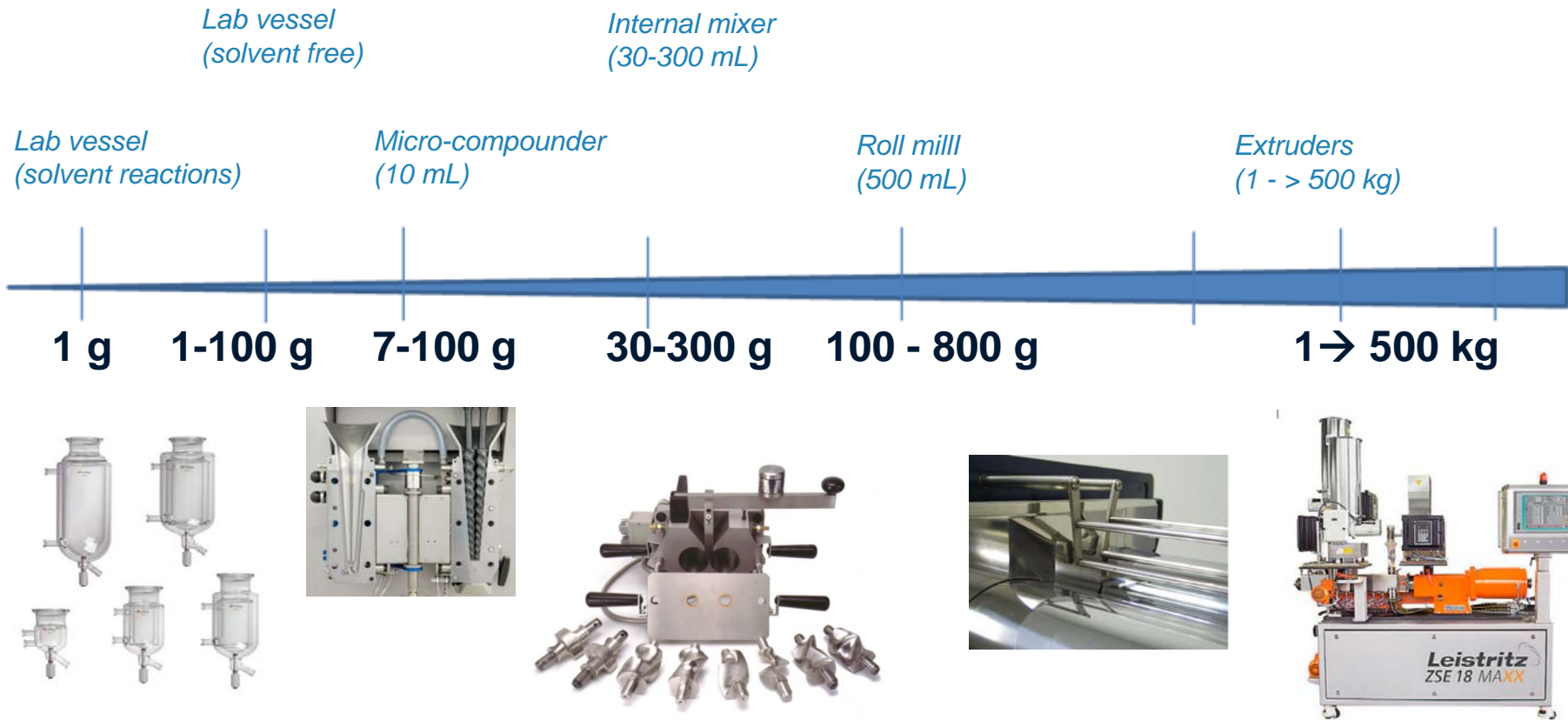




# POLYMER PROCESSING

## FROM LAB SCALE TO COMPOUNDING

“Blending/reaction toolbox” in the melt → From g to > 500 kg

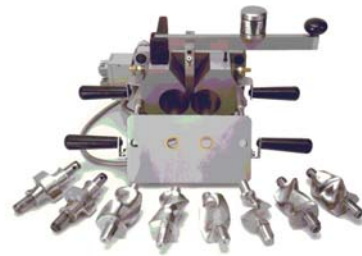


# POLYMER PROCESSING

## FROM LAB SCALE TO COMPOUNDING



3 Co-rotating twin screws (450°C)



3 Internal mixers



Roll mill external mixer



Injection molding



2 presses (50t, 450°C)



2 Micro compounders

# POLYMER PROCESSING

## FROM LAB SCALE TO COMPOUNDING



### Equipment :

- Twin-screw 16 mm L/D 40 (10 kg/h)
- 2 Twin-screw 18 mm (5-30 kg/h)
  - Up to 450 °C
  - L/D 44 – 60

### Others :

- Side-additive-liquid **gravimetric feeders**
- **Cooling** belt - bath



# POLYMER PROCESSING

## FROM LAB SCALE TO COMPOUNDING

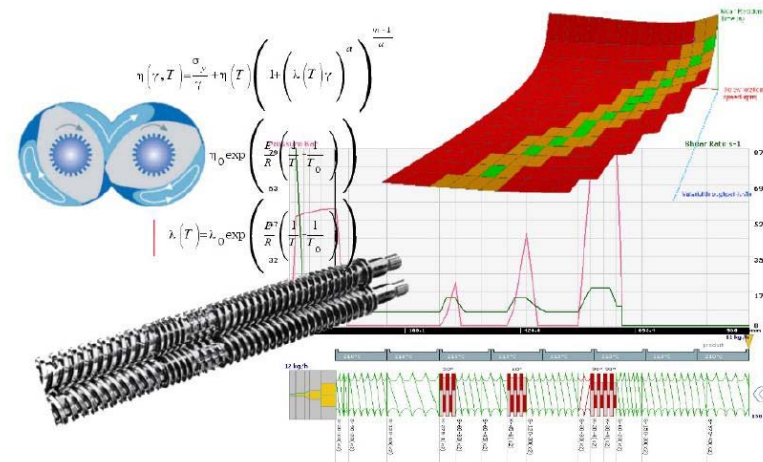
### Potential projects :

- Blending
- **Compounding**
- Masterbatch
- New polymer matrices (e.g. TPE, composites, additive manufacturing ...)
- Recycling
- Reactive extrusion
  - Compatibilization
  - Grafting : PP/MSA, PP/Peroxide, PE/Silane ...
  - Polymerization : TPU, POM, PA 6/66, PS, PET ...



### Services to the industry :

- Process optimization
  - Screw profile
  - Conditions (output, T, P, E)
- **Scale-up**





# POLYMER PROCESSING

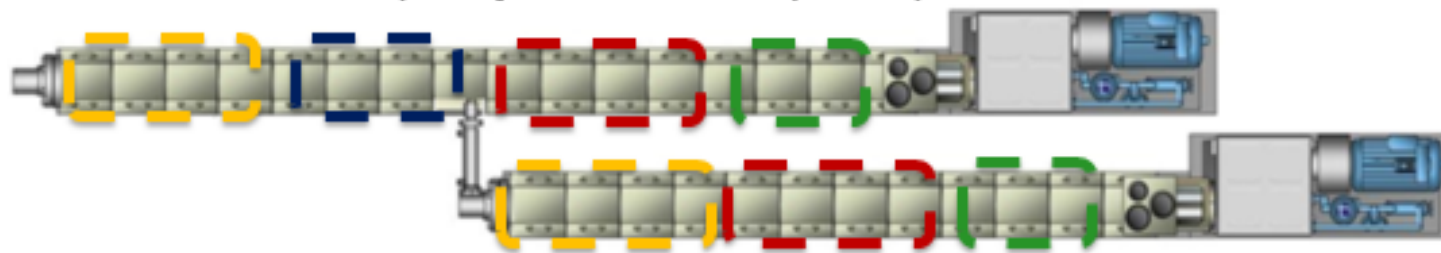
## FROM LAB SCALE TO COMPOUNDING

### Tandem extrusion :

- More fundamental approach
- Great flexibility in terms of conditions (shearing, output, T, P, E)
- More than 100 L/D max
- ➔ great potential for blending, reactive blending or synthesis

### TANDEM DESIGN

(everywhere on the profile)



11-15 barrels (~reactors)

- Composition (l/s)
- Pressure / atmosphere
- Temperature

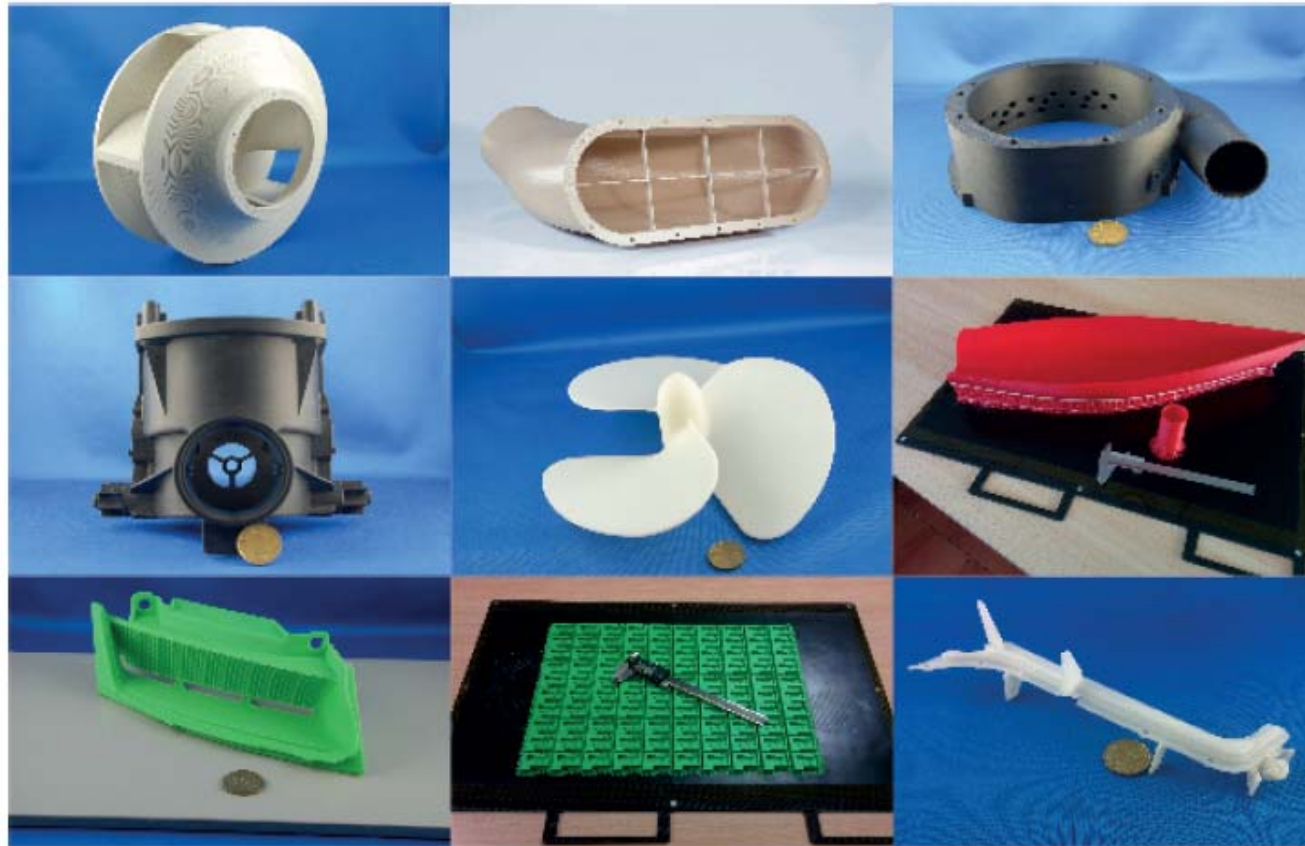
# POLYMER PROCESSING

## ADDITIVE MANUFACTURING

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



**Additive manufacturing equipment (“3D printers”) :**  
**3 FDM (Fused Deposition Modeling), 1 SLS (Selective Laser Sintering)**



## FDM (Fused Deposition Modeling)



	A4
Max build envelope*	295x195x200mm
Nozzles	2 (3 opt.)
Max nozzle T	350°C / 450°C**
Max heated bed T	135°C
Max Heated chamber	75°C
Max speed	150 mm/sec
Removable plates	yes
Mechanical accuracy XY	0,011 mm
Printable polymers	Any available**
Elastomer printing	Yes (opt.)
Minimum layer thickness	0,05 mm
Nozzle sizes	0,3 / 0,4 / 0,6 / 0,8



ABS, PCABS, PC, PS, PETG,  
PA+CF, ASA, PA+GF. TPU, TPE, PPS....

## FDM (Fused Deposition Modeling)



### Technical Specifications

Model Capabilities	<b>Apium P155</b>
Print Volume (w, d, h)	140 x 135 x 148 mm
x/y Resolution	Product Resolution: 0.5 mm
	Machine Resolution: 0.0125 mm
z Resolution	Product Resolution: 0.1 mm
	Machine Resolution: 0.05 mm
Reproducibility	0.1 mm
Minimum Layer Thickness	0.1 mm
Maximum Layer Thickness	0.3 mm
Number of Extruders	1
Nozzle Diameter	0.4 mm
Filament Diameter	1.75 mm
Print Head	Easy interchangeable nozzle
	Full metal hot end with heating up to 520 °C
	Advanced heating and cooling control
Print Bed	Optimized melt flow
	Heated up to 160 °C
Size (w, d, h)	570 x 570 x 665 mm



PEEK, POM, PEI

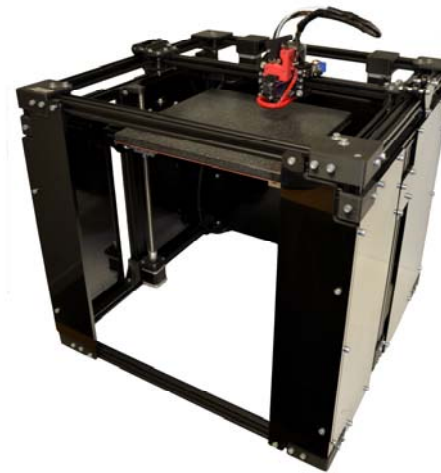


## *FDM (Fused Deposition Modeling)*

### Technical Specifications :

model :	Core 303
Print Volume :	300x300x295 mm
x/y Resolution :	Product Resolution :0,4mm
Machine Resolution :	0,02mm
z Resolution : Product Resolution :	0,1mm
Machine Resolution :	0,005mm
Minimum Layer Thickness :	0,1mm
Maximum Layer Thickness :	0,3mm
Number of Extruder:	1(direct drive)
Nozzle Diameter :	0,4mm
Filament Diameter :	1,75mm
Print Head :	full metal hot end
Print Bed:	heated up to 190° C

**D33D**



PEEK, POM, PEI with high loads of fillers

## SLS (Selective Laser Sintering)

Laser Power	14 wat CO <sub>2</sub>
laser spot dimension	0,3 mm (effective 0,2)
temperature range	up to 190 C° degrees
laser speed range	up to 64,000 pps – <3.500 mm sec
control teperature build room	thermocouple-IRsensor
deviation temperature buijd room	about +-5°
scan spacing	100 mm x 100 mm x 100 mm
scan precision X Y	100 micron
layer Z	from 50 micron
print spead in Z	up to 30 mm hour
tank powder	from 200 gr to 1,5 Kg
minimum powder required	250-300 grams



For PA matrices mainly ...

# POLYMER PROCESSING TEAM



**Pr. Daniel Schmidt**

*B.S. in Materials Sc. & Eng.  
B.S. in Chemistry*

**Expertise and interests:**

- Thermoset chemistry
- Ceramics and semiconductors from molecular precursors
- Materials characterization
- Sustainability



**Dr. Roberto Quintana**

*BSc & MSc Chemical Eng.*

**Expertise and interests:**

- Melt polymerization
- Reactive extrusion
- Extrusion in-situ monitoring
- In-situ nanocomposite synthesis, tandem extrusion
- Surface functionalization



**Dr. Vincent Berthé**

*BSc & MSc Chemistry  
MBA*

**Expertise and interests:**

- Polymer formulation
- Polymer for structural composites
- Additive manufacturing
- Compatibilization (highly different viscosities)
- Reactive extrusion



# COMPOSITE PROCESSING OVERVIEW

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



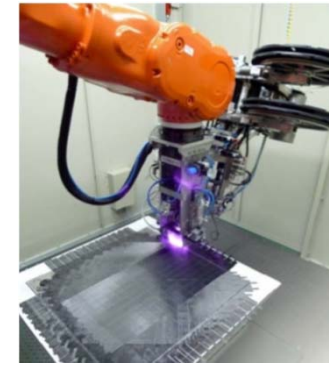
IR Welding  
machine

*Reception: March 2018*



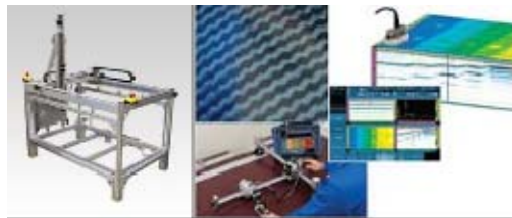
Robotized  
stamping press

*Reception: June 2018*



Laser assisted  
ATL & winding

*Reception: Nov. 2018*



US NDT immersion tank

*Reception: March 2018*



RTM & Infusion injection  
unit + Cure monitoring

*Reception: March 2018*



420°C  
Oven(3,5m<sup>3</sup>)

*Reception: March 2018*



# CHARACTERIZATION

## SOME CUTTING-EDGE EQUIPMENT...



Solid state and  
liquid state multi-  
nuclear NMR (600  
MHz)



Advanced  
rheometer



µWT machine:  
RXsolutions Easytom



AFM machine: Asylum  
Infinity

*Reception: January  
2018*

*Reception: Mars 2018*

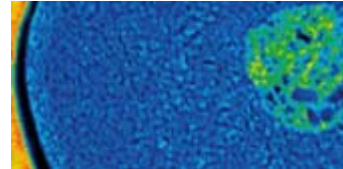
# MATERIALS CHARACTERIZATION & TESTING

*SUPPORT FOR THE INDUSTRY*

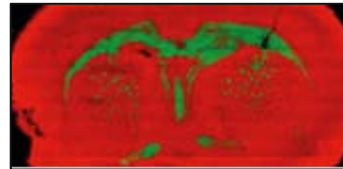
LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



Elemental and isotopic  
analysis



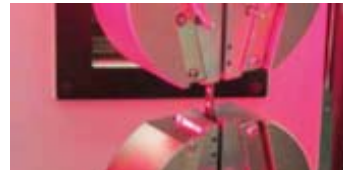
Molecular analysis



Structure, morphology  
and topography



Mechanical testing and  
accelerated ageing



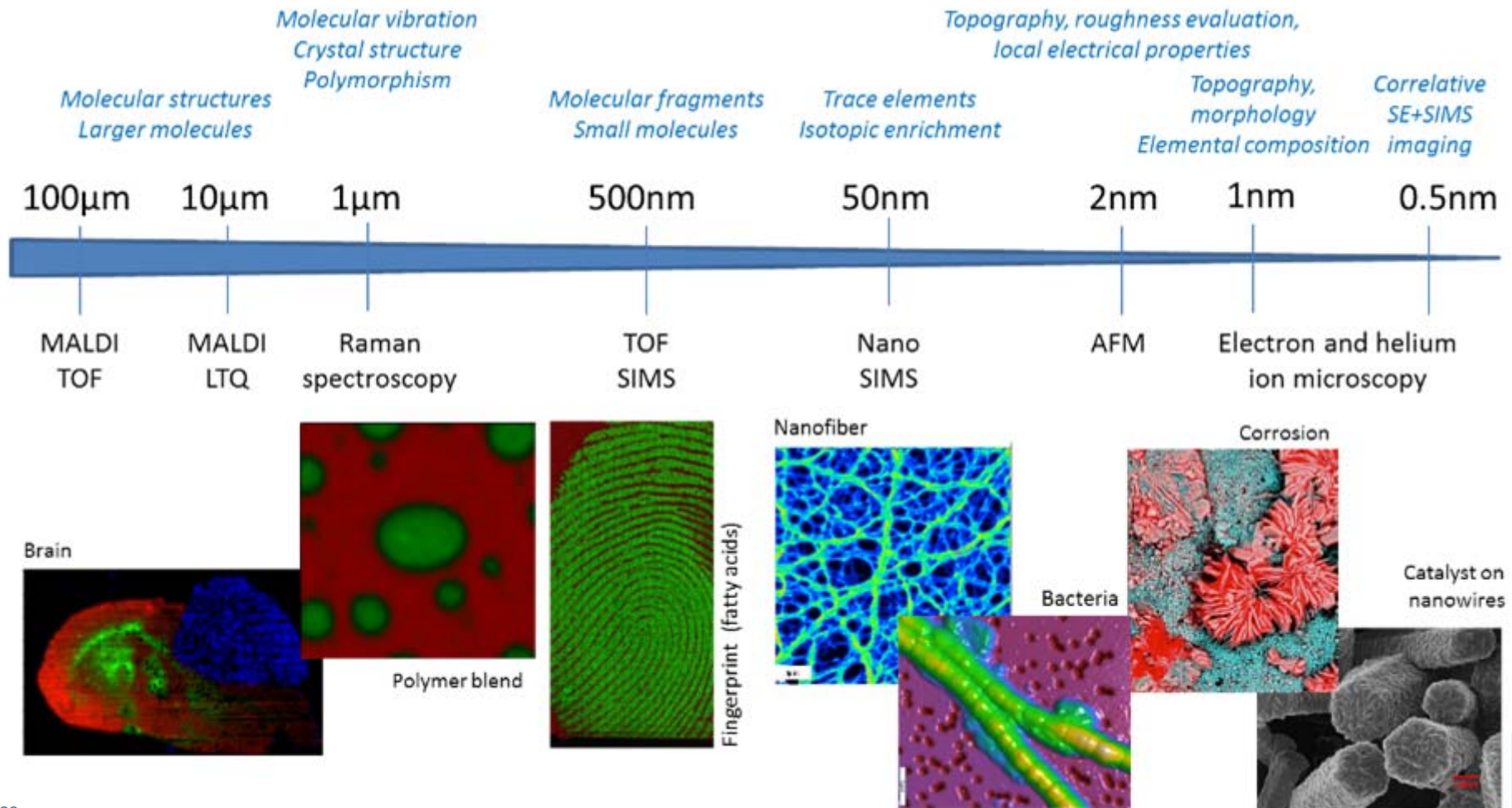
Fire testing



# MATERIALS CHARACTERIZATION & TESTING

## SUPPORT FOR THE INDUSTRY

“Characterization toolbox” for imaging → From micro to nano

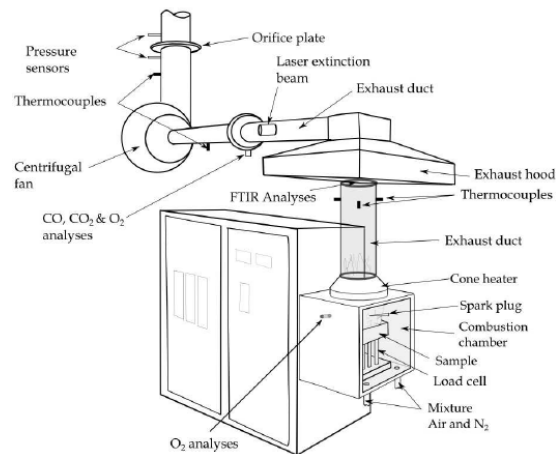


# MATERIALS CHARACTERIZATION & TESTING

## FLAME RETARDANCY

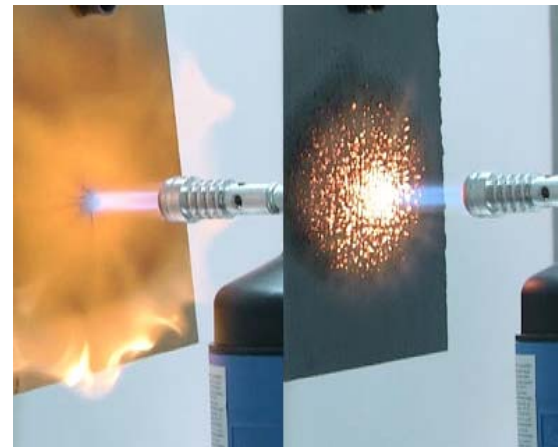
The use of complementary techniques:

- **Cone calorimeter** coupled to FTIR
- Micro-Calorimeter (PCFC)
- Smoke chamber coupled to FTIR
- Flammability chamber (UL94)



They allow the determination of :

- **Heat release** rate, time to ignition ...
- Heat capacity, heat release rate
- Smoke opacity and toxicity
- Extinguishing or flame spread ( $V_{0,1,2}$ )



*LIST's analytical capabilities and expertise have already proven useful to the **packaging, building, automotive, transport and plastics industries***



# POLYMER SYNTHESIS ACTIVITIES

## MAIN EQUIPMENT

Use of complementary tools:

- Full sets of chemistry lab benches
- 500 m<sup>2</sup> dedicated to organic and polymer synthesis
- 2 glove boxes (N<sub>2</sub> and Ar)
- 1 polycondensation reactor (100g)
- 1 synthesis reactor (up to 5L) ...



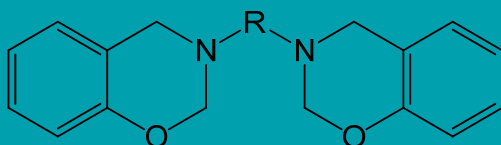
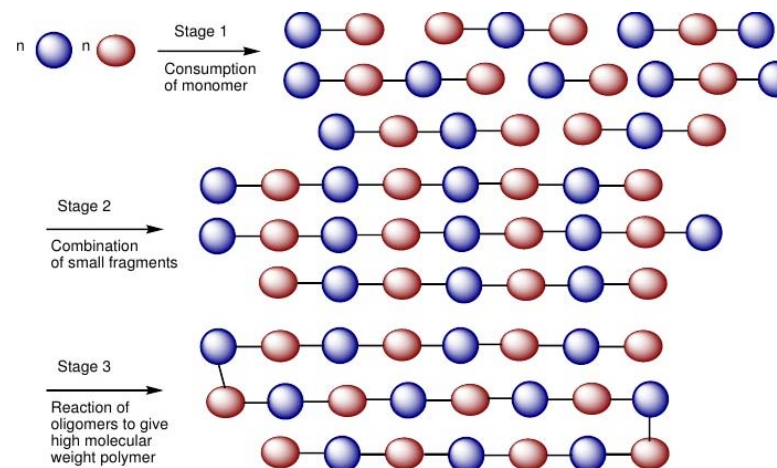


# POLYMER SYNTHESIS ACTIVITIES

## MAIN COMPETENCES

Polymerizations:

- **Polycondensation**
- Anionic polymerization
- Cationic polymerization
- Radical polymerization
- ...



Chemical structure allows  
the use of **Bio-based  
phenolic compounds**

Types of polymers prepared:

- Polyesters
- Epoxy
- **Benzoxazine**
- Polyurethane
- Rubbers and elastomers
- Ionic liquid polymers
- ...

# LIFE CYCLE SUSTAINABILITY AND RISK ASSESSMENT

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY



## OUR MAIN OBJECTIVE, EXPERTISE FIELDS AND FEATURES

### Main objective:

*Develop Sustainability assessment **methods and tools adapted to each decision-making context***

### In-house expertise fields:

- ✓ *Circular Economy approaches (ex: eco-design, recycling, industrial symbiosis)*
- ✓ *Life-Cycle Assessment (LCA): attributional, consequential, Input/Output, hybrid*
- ✓ *Eco-system services*
- ✓ *Mathematical optimisation*
- ✓ *MFA (Material Flow Analysis)*
- ✓ *Uncertainties calculations for LCA*
- ✓ **REACH helpdesk for Luxembourg**
- ✓ *Toxicology and eco-toxicology (3D lab models)*
- ✓ *Life-Cycle Costing (LCC)*

### Features of our R&D activities:

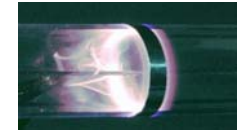
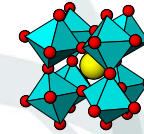
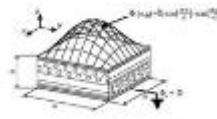
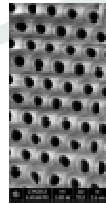
*Coupling LCA with other expertise fields (e.g. MFA, GIS data, risk assessment...) to refine modellings and improve the quality of input data.*

# LIFE CYCLE SUSTAINABILITY AND RISK ASSESSMENT

## INDUSTRIAL AND INSTITUTIONAL PARTNERS

LUXEMBOURG  
INSTITUTE OF SCIENCE  
AND TECHNOLOGY





# Thanks for your attention

## LIST – MRT Department

Catalyzes the translation of smart materials  
towards industrial innovation

Dr. Vincent Berthé  
*Senior research and technology associate*  
**LIST, NCC-L Polymer Processing**  
*vincent.berthe@list.lu*