



1st International Conference of
TWAS Young Affiliates Network



Top Science with Low Funding



Assoc. Prof. Carolina P. Naveira Cotta

Laboratory of Nano and Microfluidics and Micro-Systems – LabMEMS

Mechanical Engineering Program – PEM/COPPE

Engineering of Nanotechnology Program – PENT/COPPE

Universidade Federal do Rio de Janeiro - UFRJ



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Low Funding Aided by Creativity, Theory, and Networking

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MEMS na COPPE/UFRJ
(2011 ...)



LABMEMS

Laboratório de Nano e Microfluídica e Microsistemas

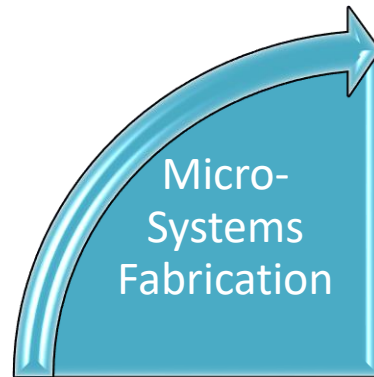
Fields/Areas:

- Heat & Mass Transfer and Fluid Flow in Micro and Nano Scale
- Continuum Mechanics and Complex Fluids



Fields/Areas:

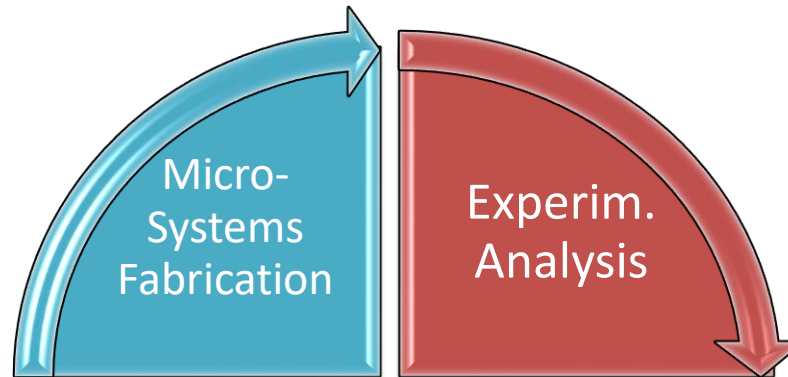
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Fields/Areas:

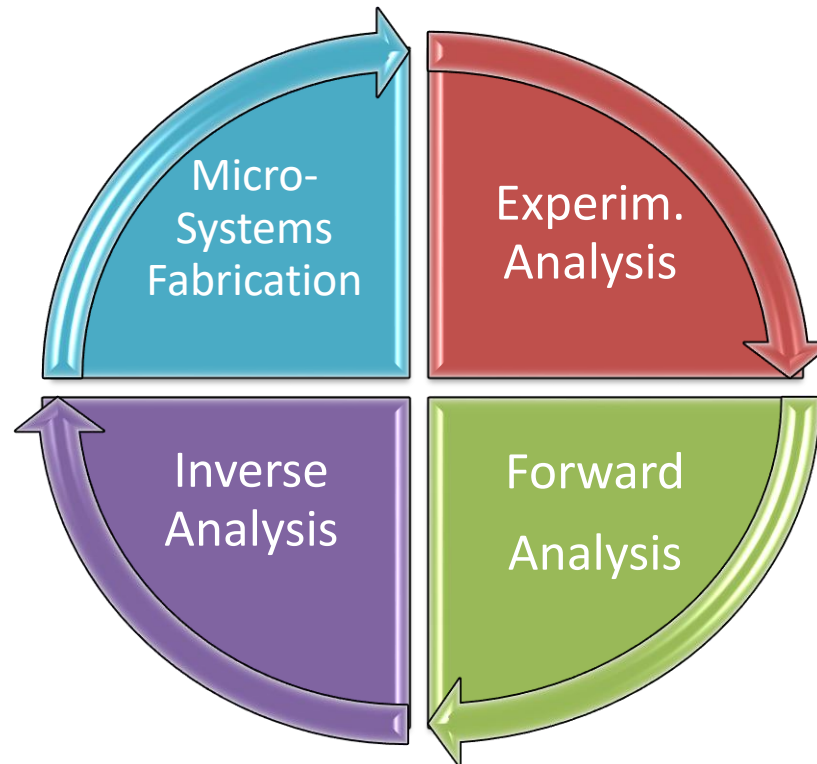
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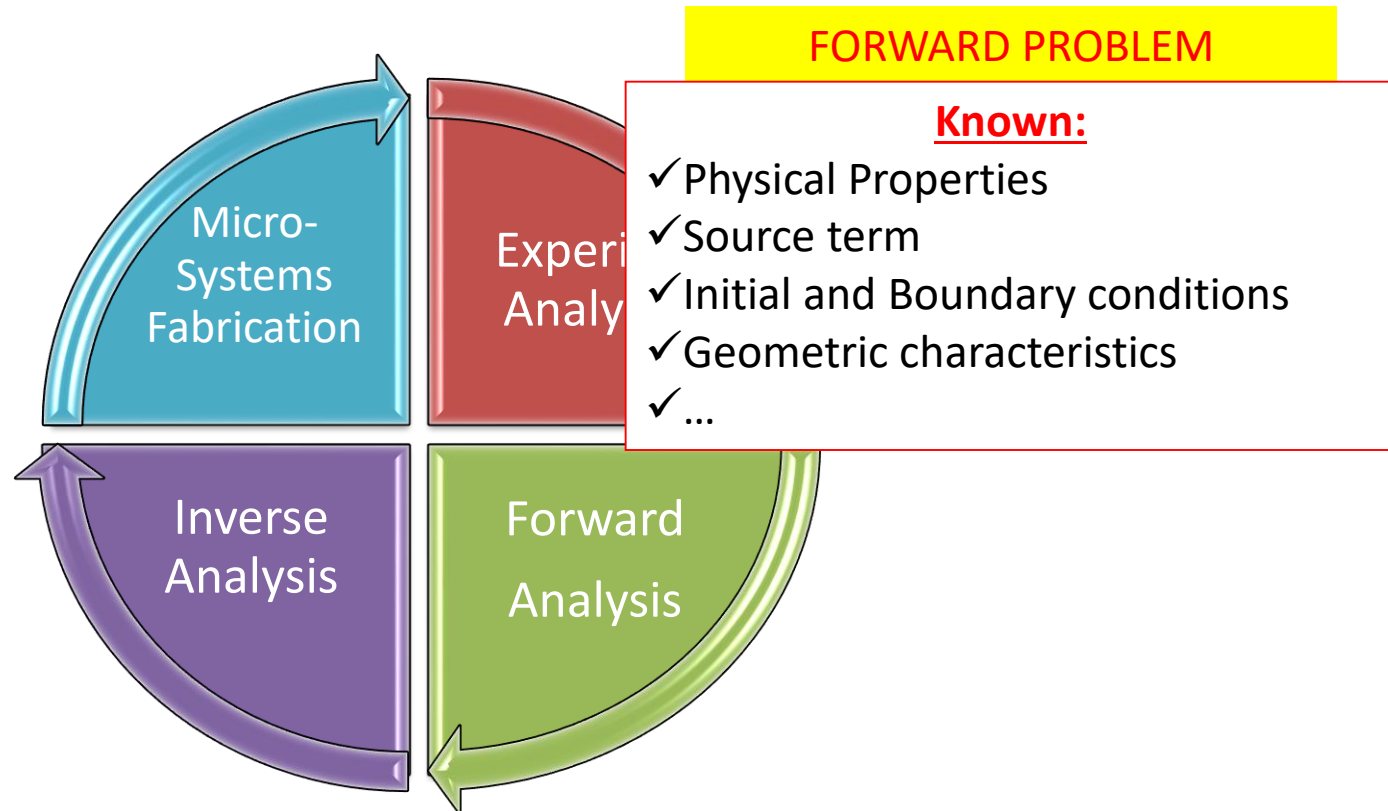
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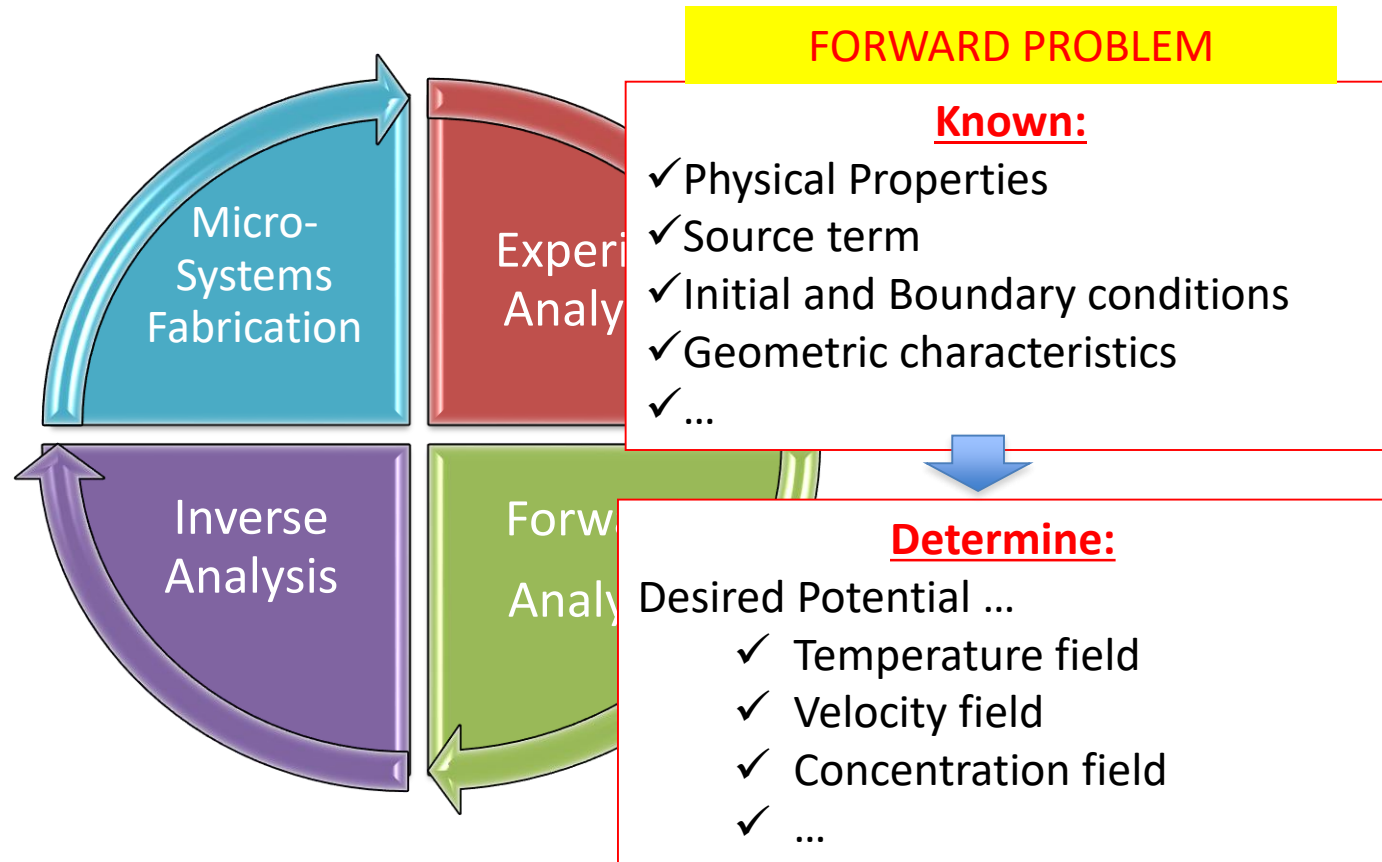
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Fields/Areas:

- Heat & Mass Transfer and Fluid Flow in Micro and Nano Scale
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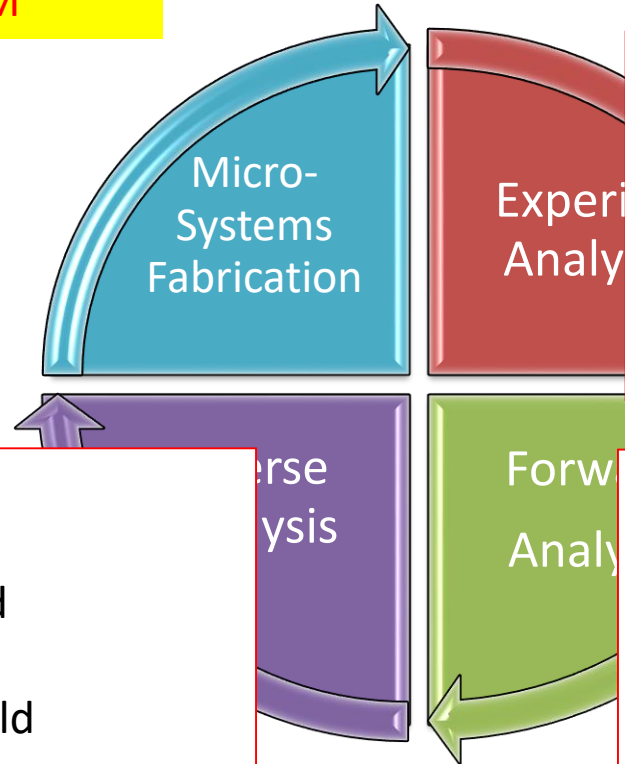


Fields/Areas:

- Heat & Mass Transfer and Fluid Flow in Micro and Nano Scale
- Continuum Mechanics and Complex Fluids

INVERSE PROBLEM

FORWARD PROBLEM



- Known:**
- ✓ Physical Properties
 - ✓ Source term
 - ✓ Initial and Boundary conditions
 - ✓ Geometric characteristics
 - ✓ ...

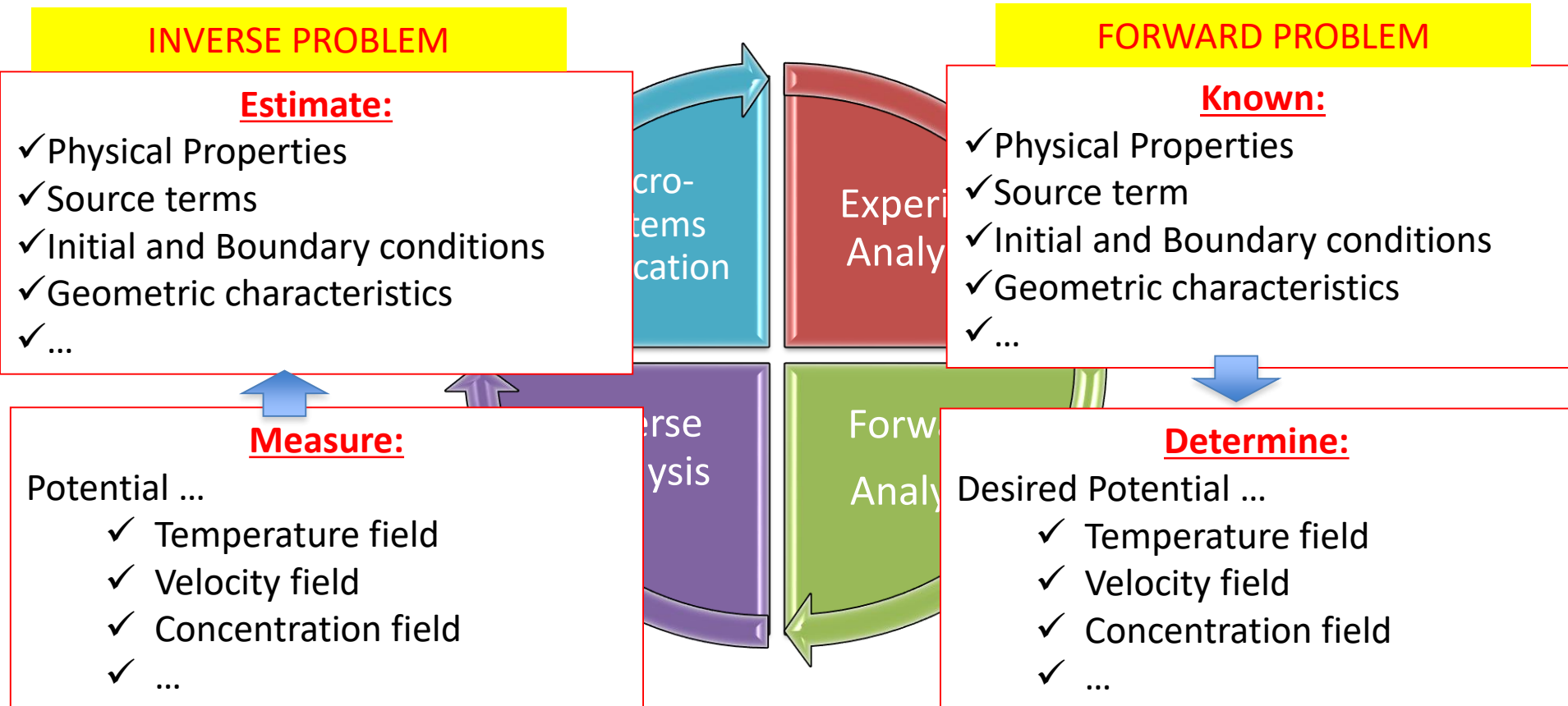
- Measure:**
- Potential ...
 - ✓ Temperature field
 - ✓ Velocity field
 - ✓ Concentration field
 - ✓ ...

- Determine:**
- Desired Potential ...
 - ✓ Temperature field
 - ✓ Velocity field
 - ✓ Concentration field
 - ✓ ...

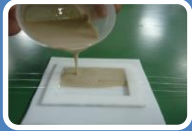


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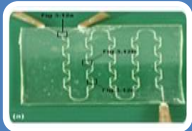
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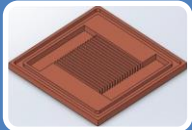
Application Areas



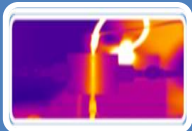
Nanocomposites and Nanofluids



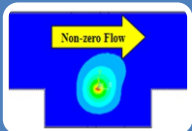
Micro reactors



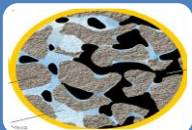
Micro-Heat Exchangers



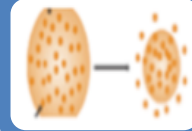
Micro-Heat Spreaders



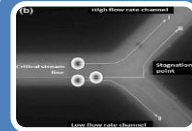
Micro-Sensors



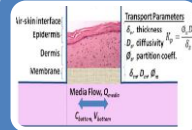
Micro-Models of Porous Media



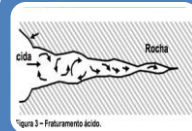
Controlled Drug Release



Cell separation

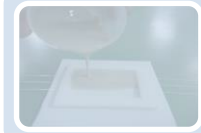


Human on a chip (cell toxicology)

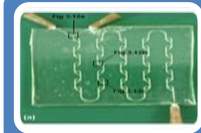


EOR – Enhanced Oil Recovery

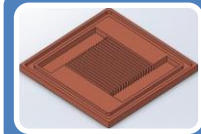
Application Areas



Nanocomposites and Nanofluids



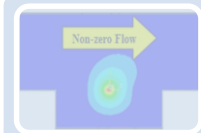
Micro reactors



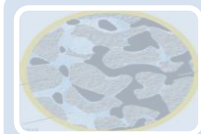
Micro-Heat Exchangers



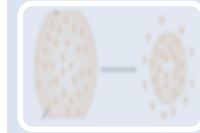
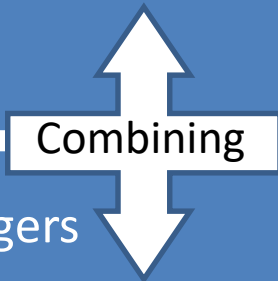
Micro-Heat Spreaders



Micro-Sensors



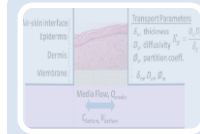
Micro-Models of Porous Media



Controlled Drug Release



Tumor cell separation

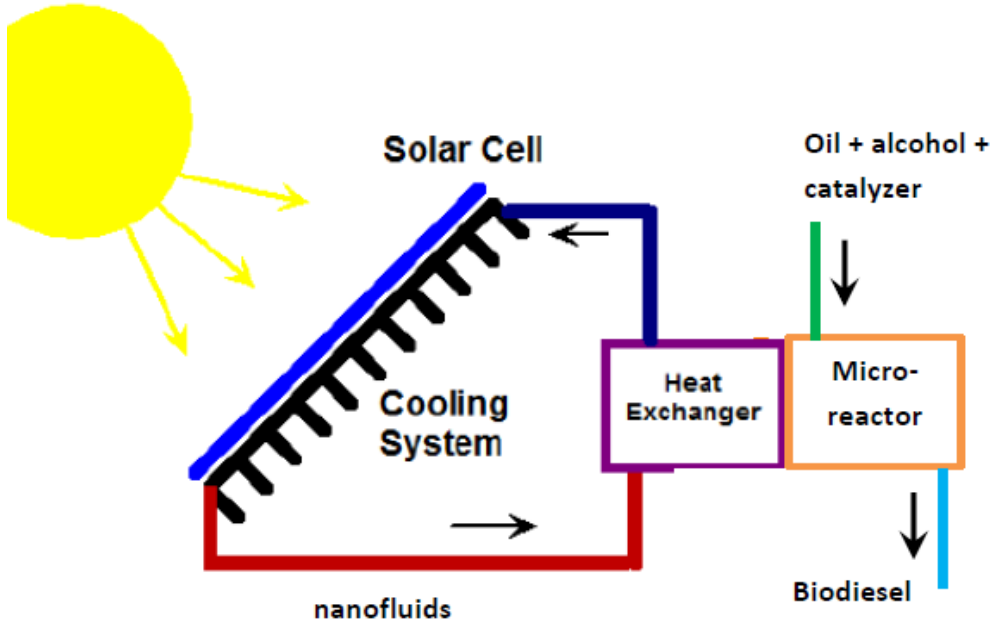


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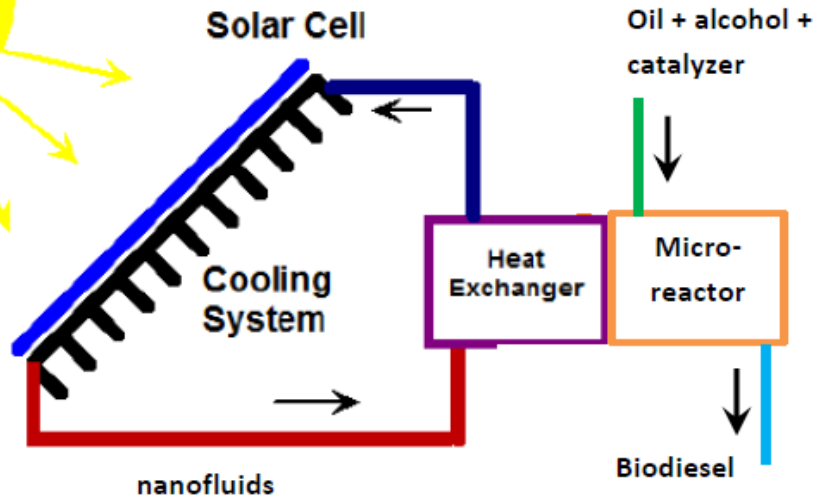
R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)



- Rejected heat can be used for other purposes (desalination, heating, cooling, **biodiesel production**, etc) ;

R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)

Network !!!



UCL, UFU & COPPE/UF RJ
Project

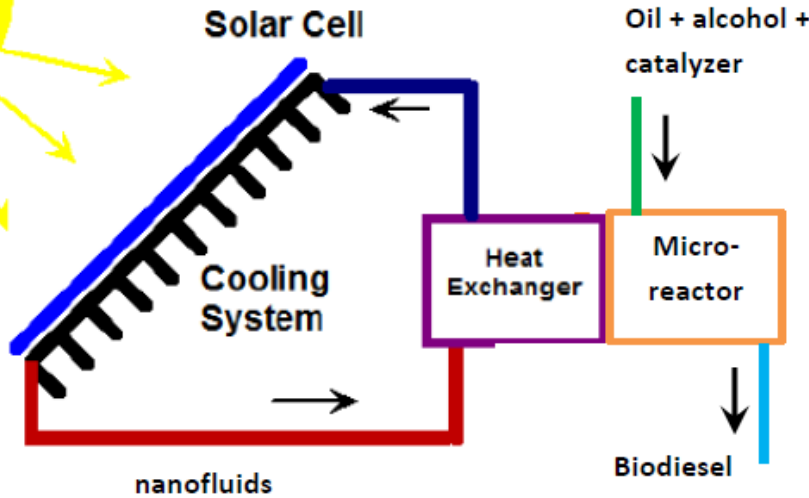
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R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)



UCL, UFU & COPPE/UF RJ Project

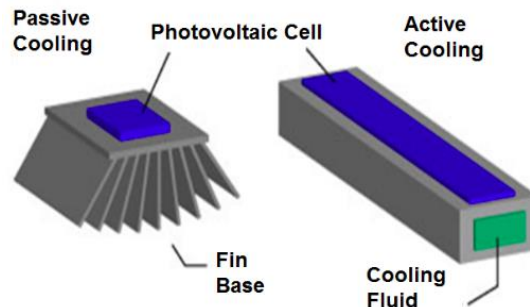
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UFU HCPV system

High Concentration: 800 suns

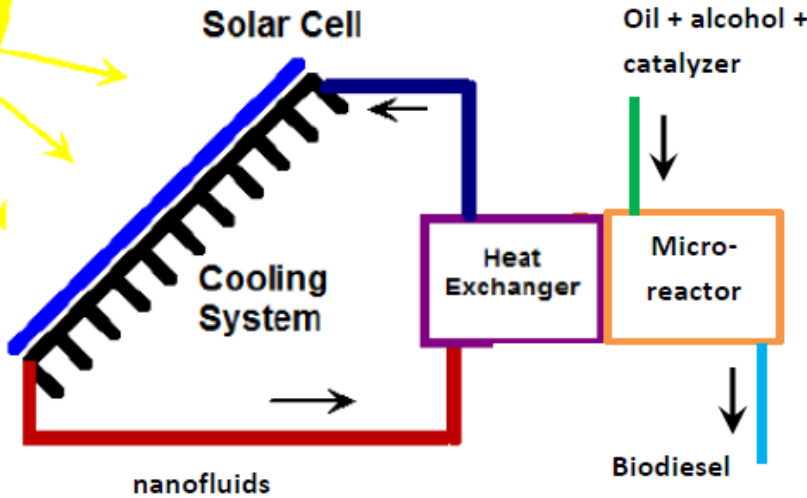
Power Generation: 1.5kVA



R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)

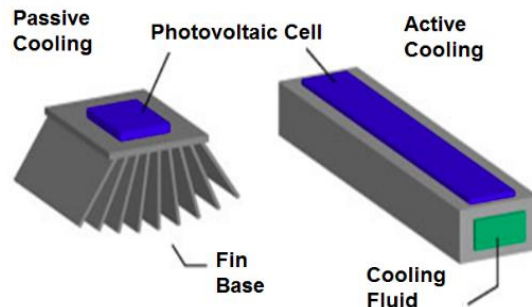


UCL, UFU & COPPE/UFRJ Project

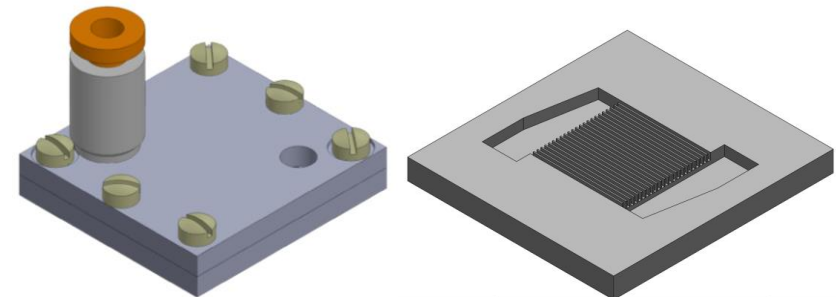


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UFU HCPV system
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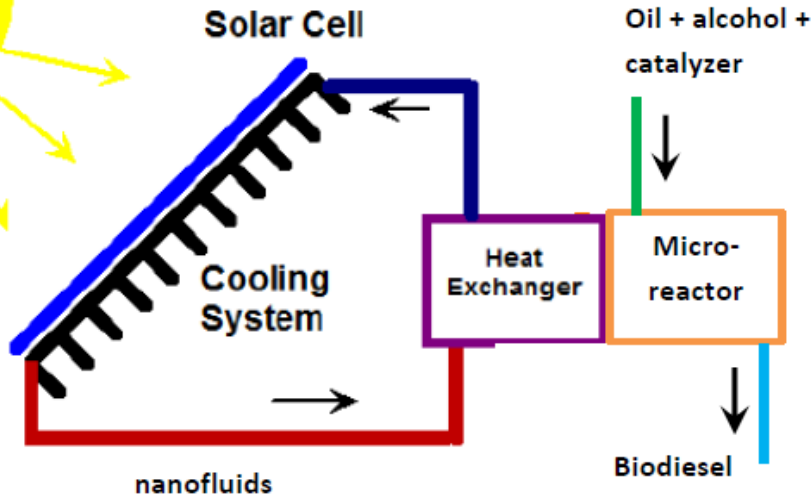
LabMEMS/COPPE UFRJ Optimized
 Micro Heat Exchanger
 For the HCPV cooling system



R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)

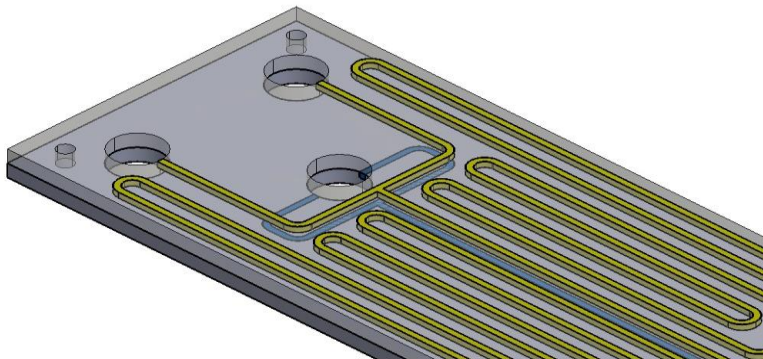


UCL, UFU & COPPE/UF RJ Project

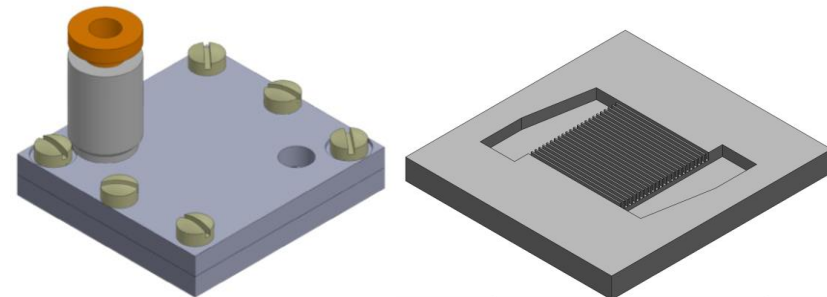


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LabMEMS/COPPE UFRJ Integrated micro-heat exchanger and micro reactor;



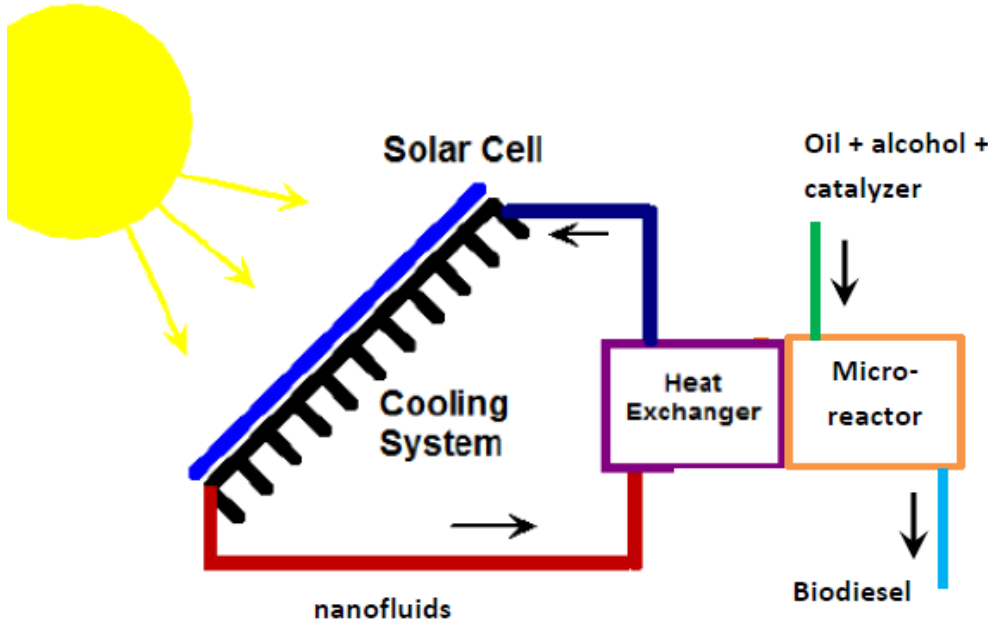
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R&D Challenges : Biodiesel Production Intensification with Heat Recovery from High Concentration Photovoltaic Cells (HCPV)



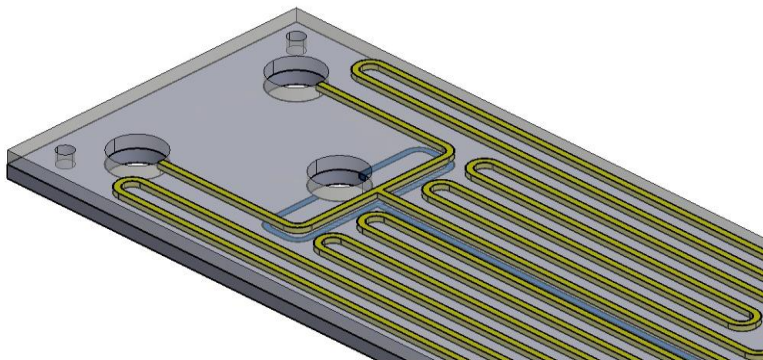
UCL, UFU & COPPE/UF RJ Project



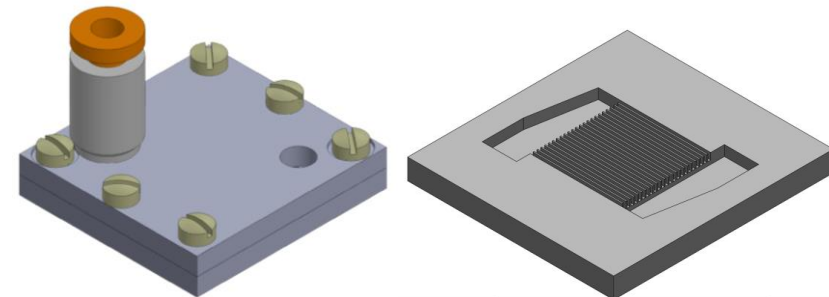
SIGNIFICANT POTENTIALS...

- Portable biodiesel production;
- Short residence time;
- Continuous mode;

LabMEMS/COPPE UFRJ Integrated micro-heat exchanger and micro reactor;



LabMEMS/COPPE UFRJ Optimized Micro Heat Exchanger For the HCPV cooling system



R&D Challenges : **Biodiesel Production** in micro reactors

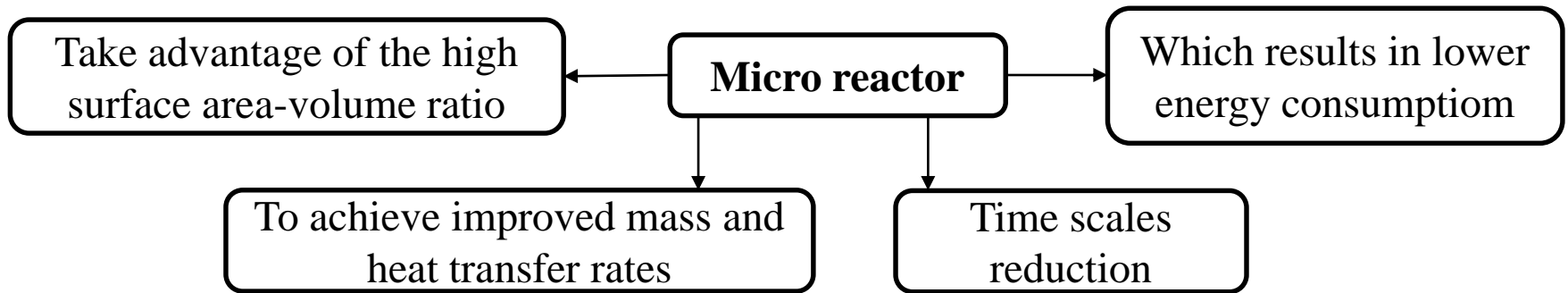


Fig. : Advantages of microreactors in reactional systems.

R&D Challenges : Biodiesel Production in micro reactors

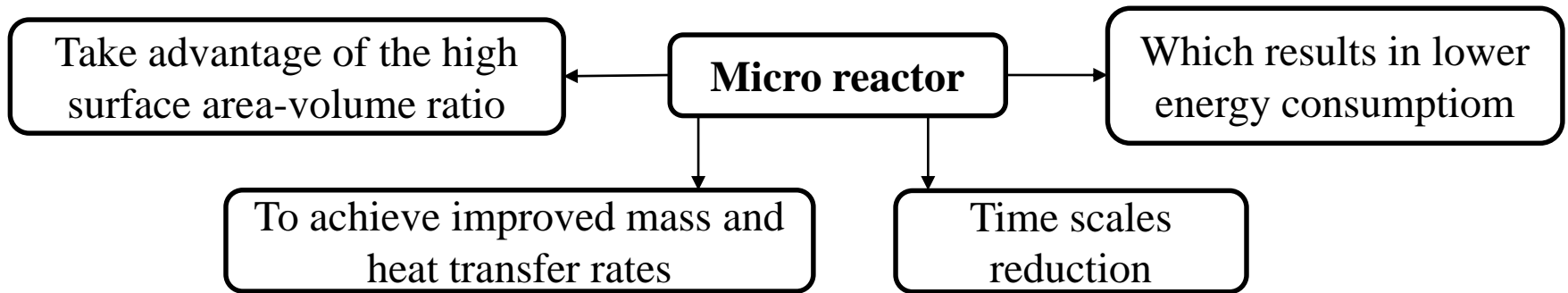


Fig. : Advantages of microreactors in reactional systems.

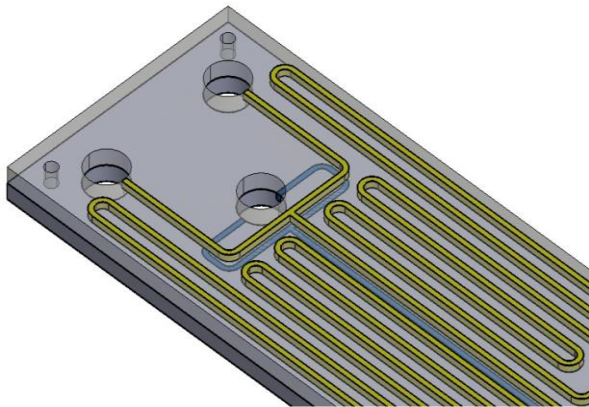


Fig. Single micro reactor;

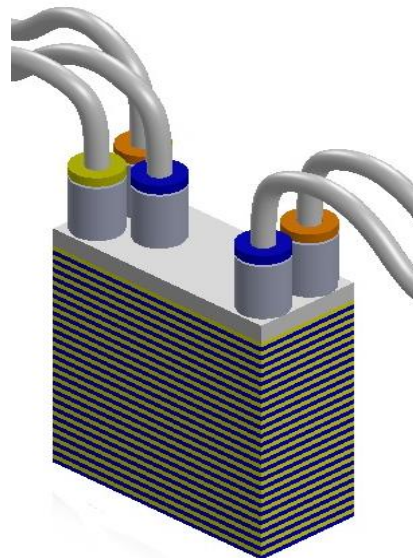


Fig. Module of micro reactors

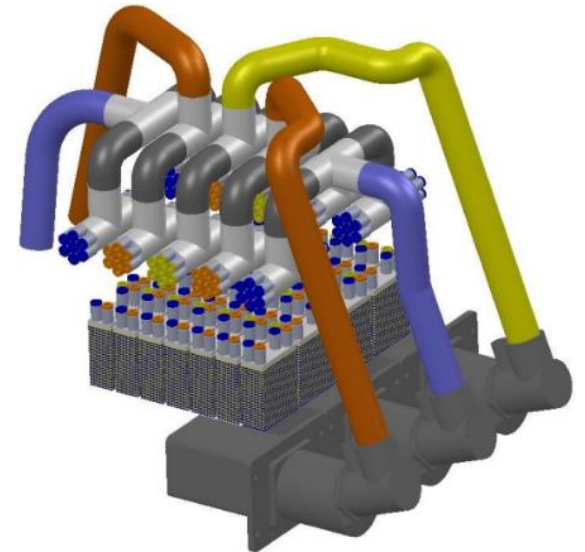


Fig. Complete manifold of micro reactors

R&D Challenges : Biodiesel Production in micro reactors

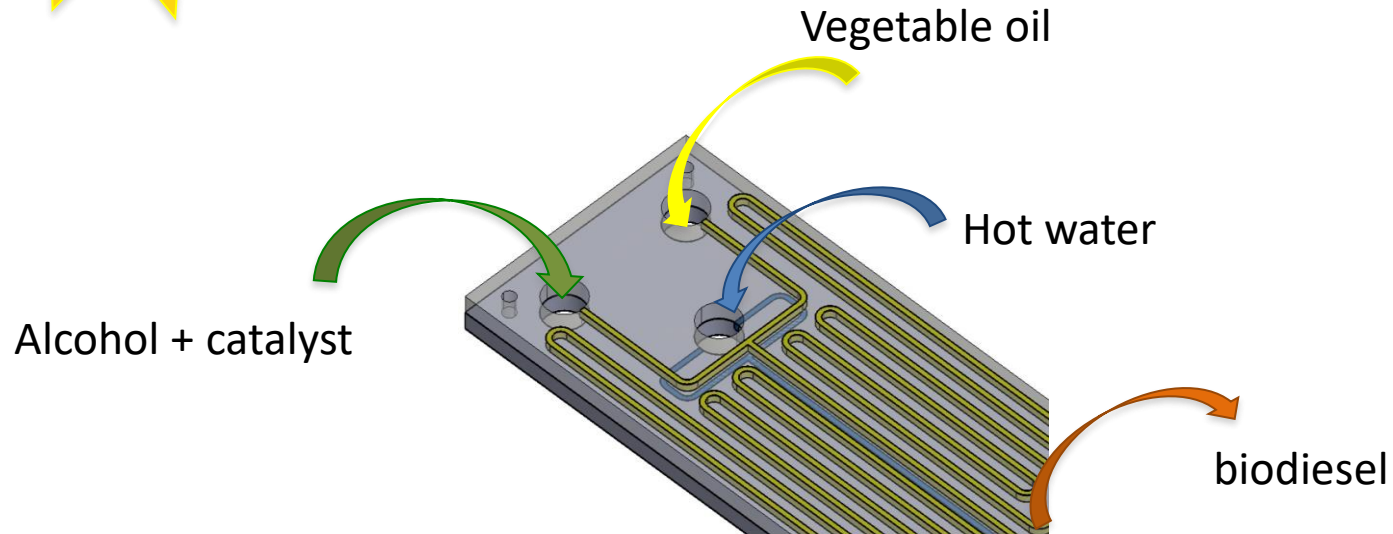
➤ Design of optimized micro-reactor

Theoretical Analysis

Representative mathematical model for **theoretical predictions**

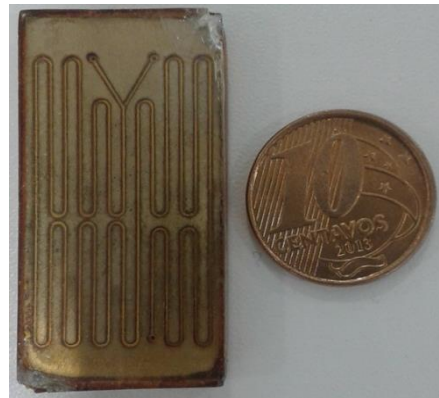
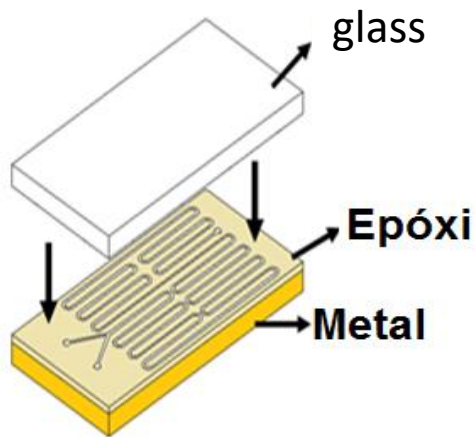
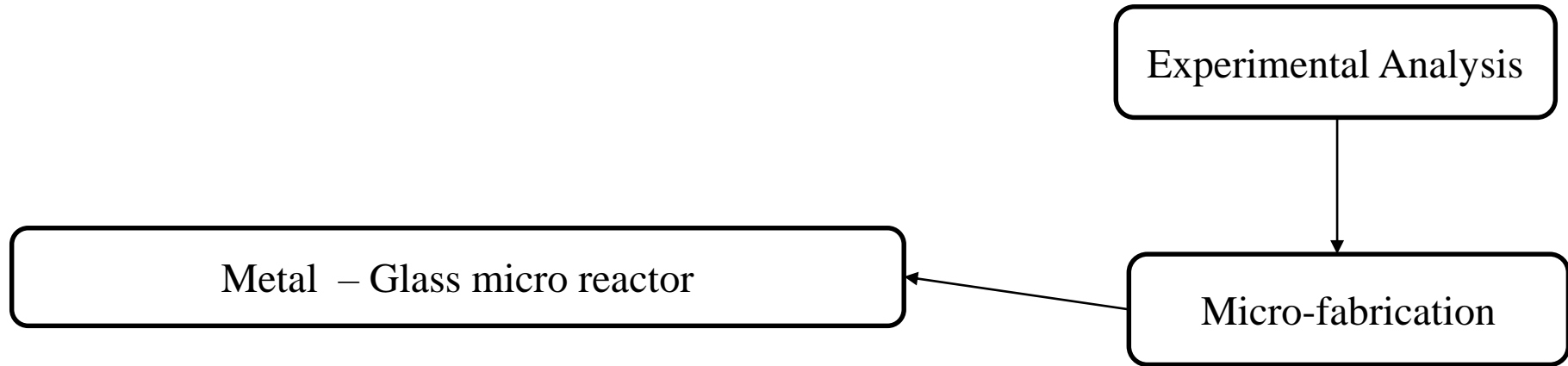
Experimental Analysis

Uncertainties in the measurements;

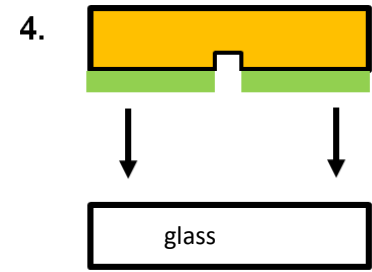
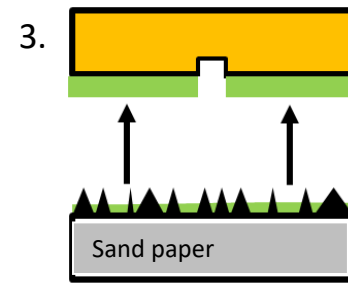
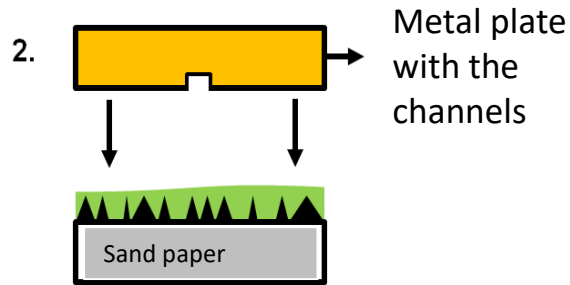
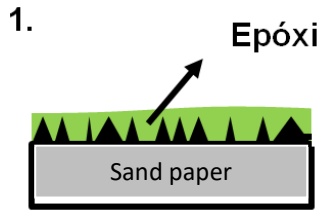
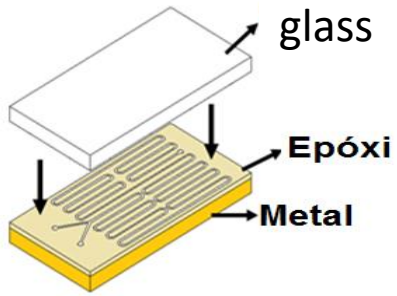


R&D Challenges : Biodiesel Production in micro reactors

➤ Design of optimized micro-reactor



R&D Challenges : Biodiesel Production in micro reactors



R&D Challenges : Biodiesel Production in micro reactors

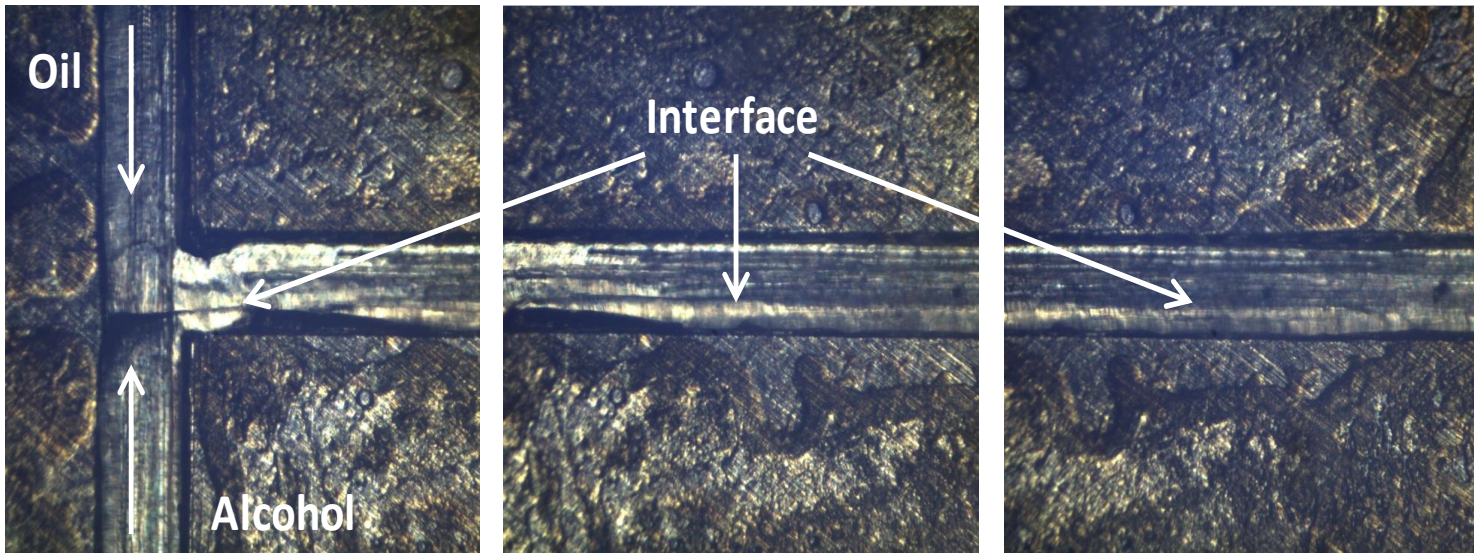
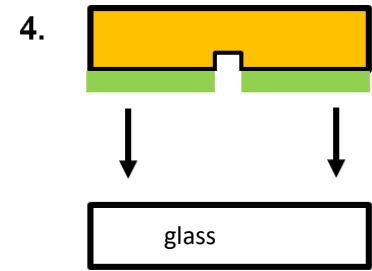
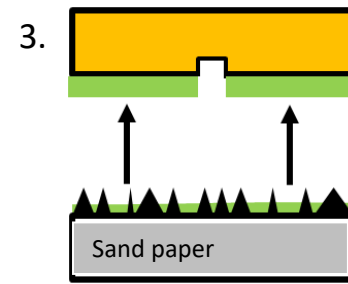
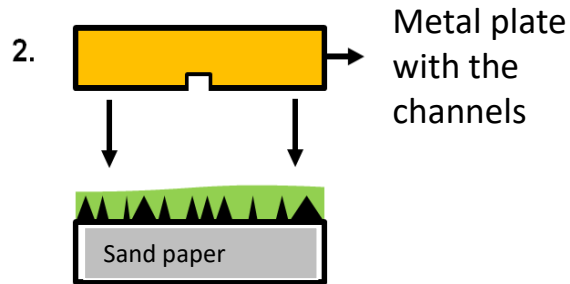
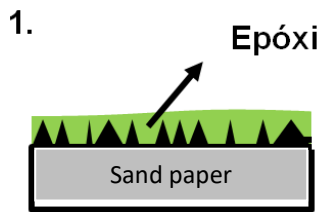
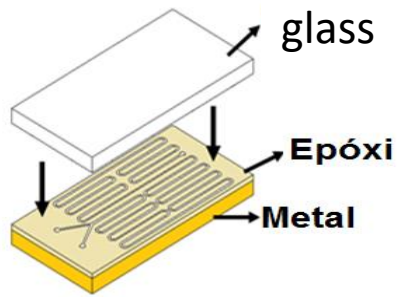
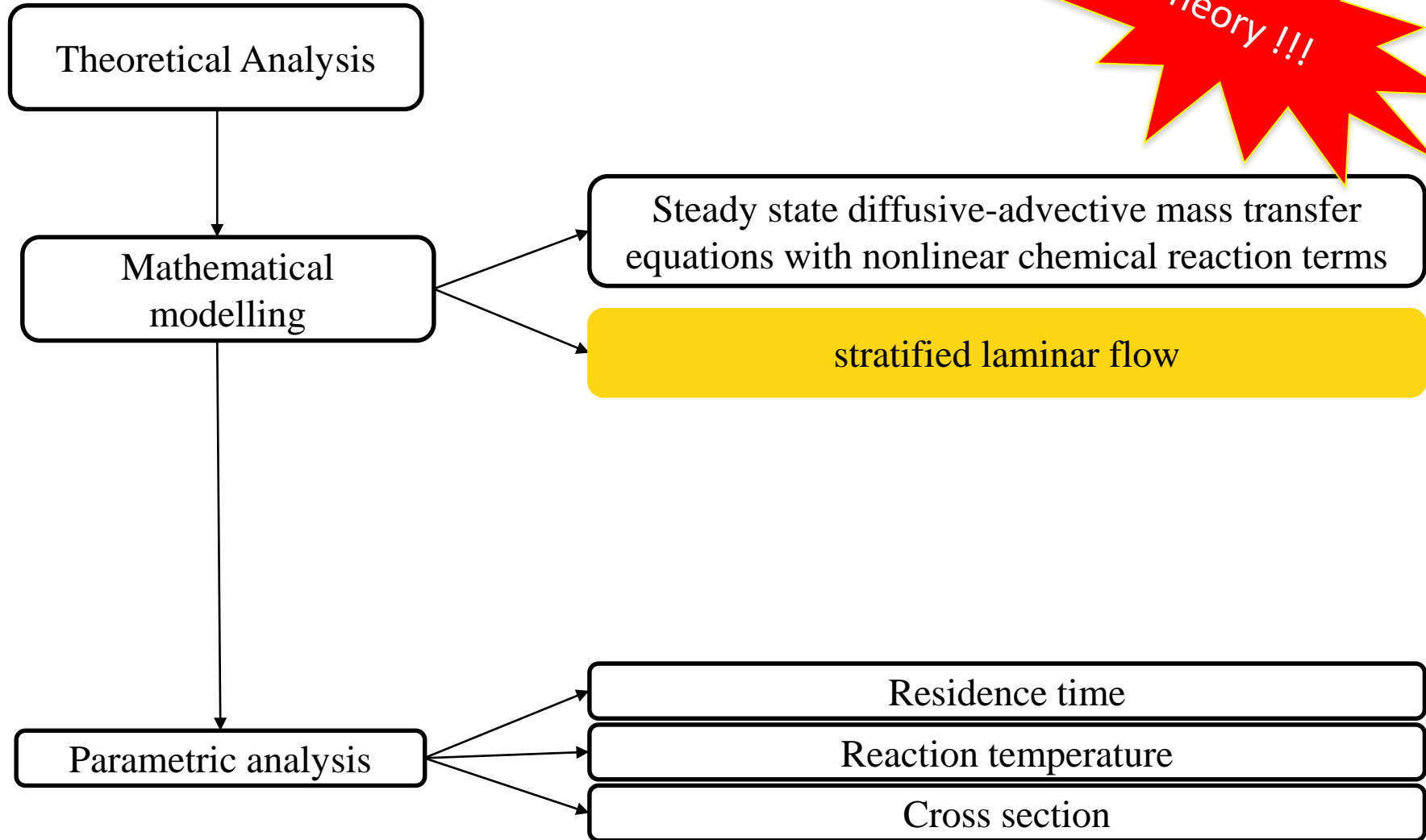


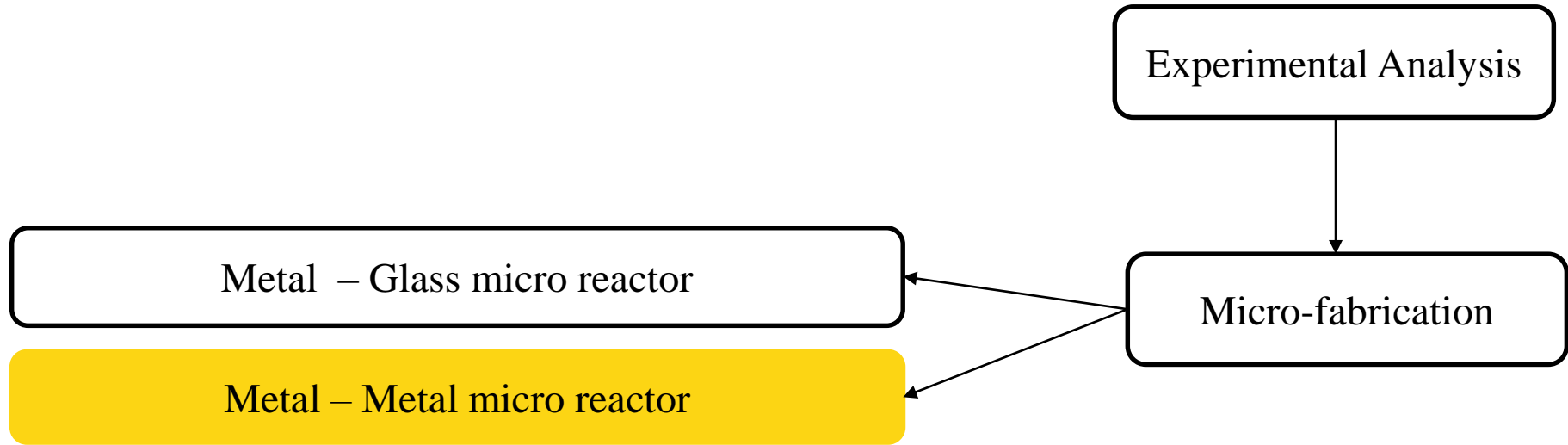
Fig.: Exp. observation of stratified flow pattern formed by the alcohol and the vegetable oil.

R&D Challenges : Biodiesel Production in micro reactors

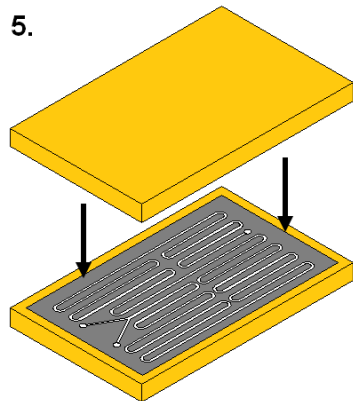
➤ MODELLING



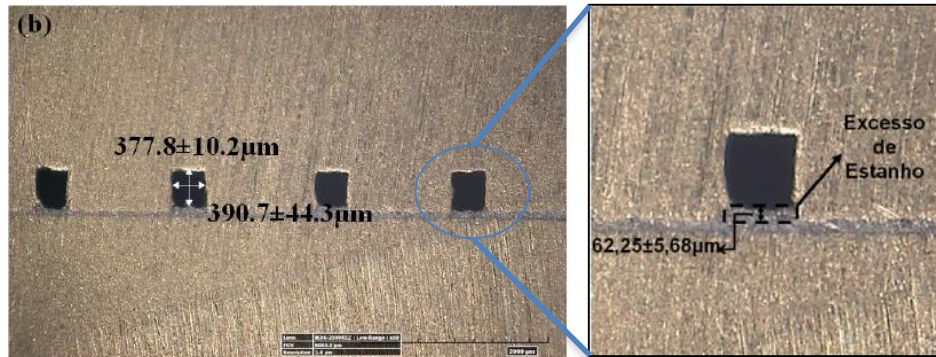
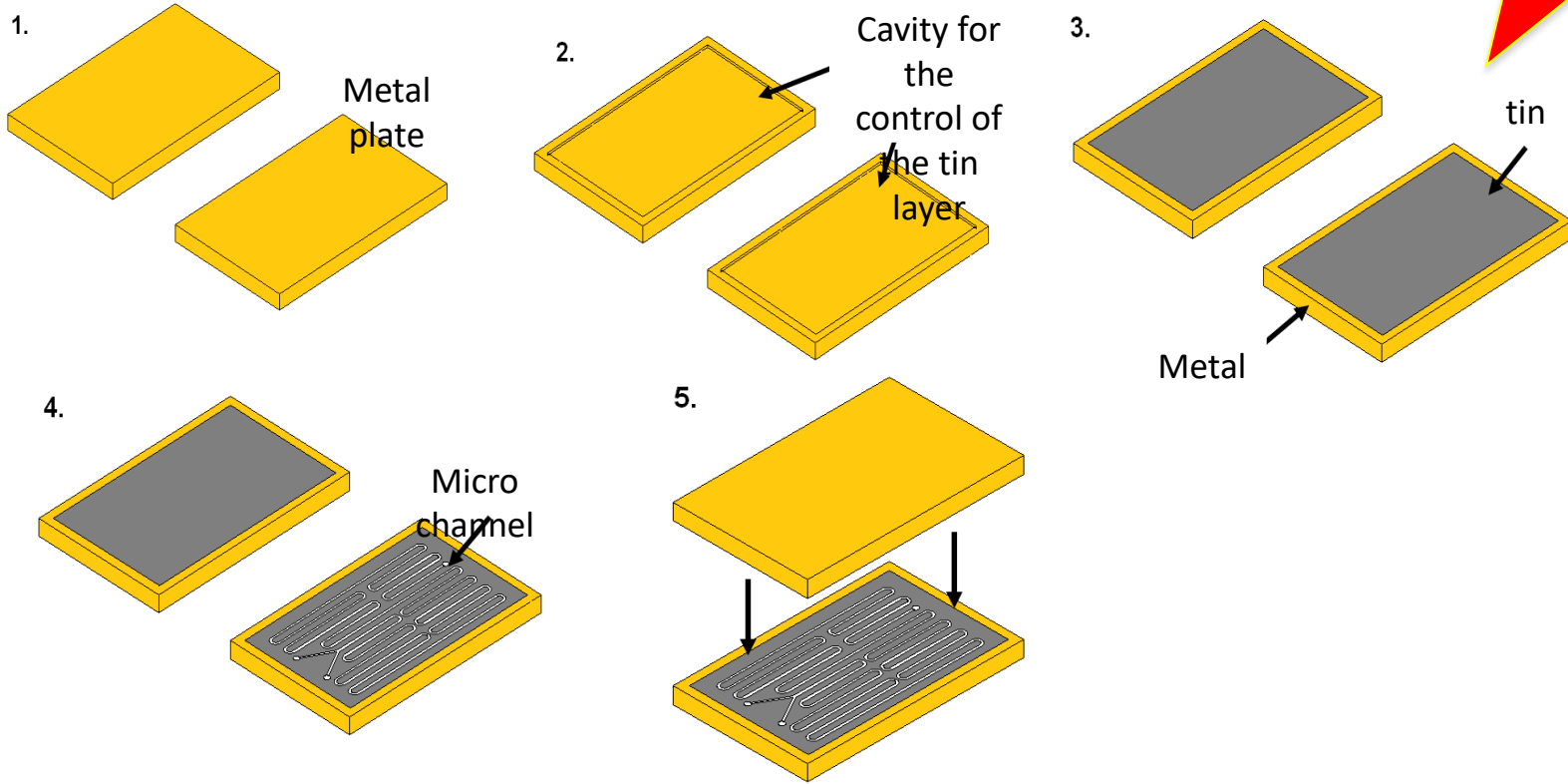
R&D Challenges : Biodiesel Production in micro reactors



5.



Metal-Metal Micro reactor



R&D Challenges : Biodiesel Production in micro reactors

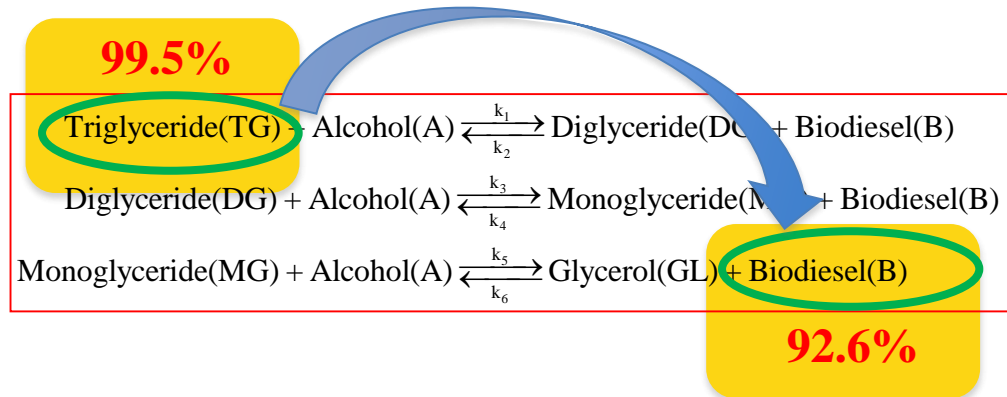
➤ Triglyceride conversion during the ethanol transesterification reaction

Ethanol/Soybean Oil ratio: 20:1

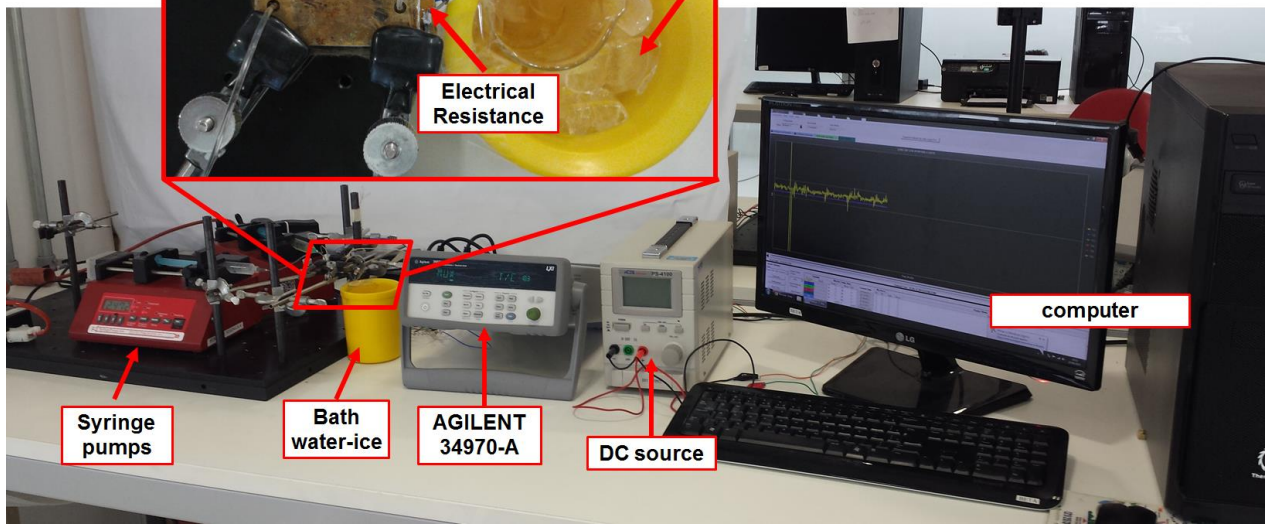
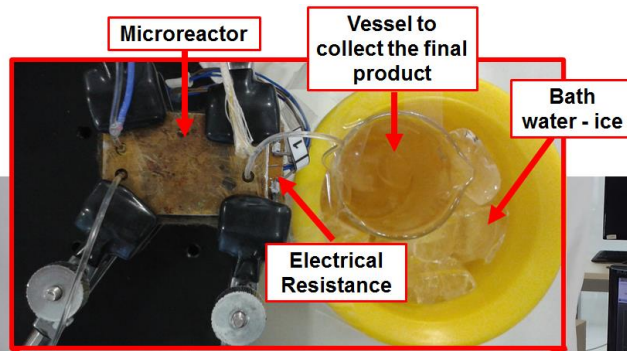
Catalyst: NaOH 1,5% wt oil

Reaction temperature: 51,9° C

Residence time: 46 seconds



➤ Experimental Setup



R&D Challenges : Biodiesel Production in micro reactors

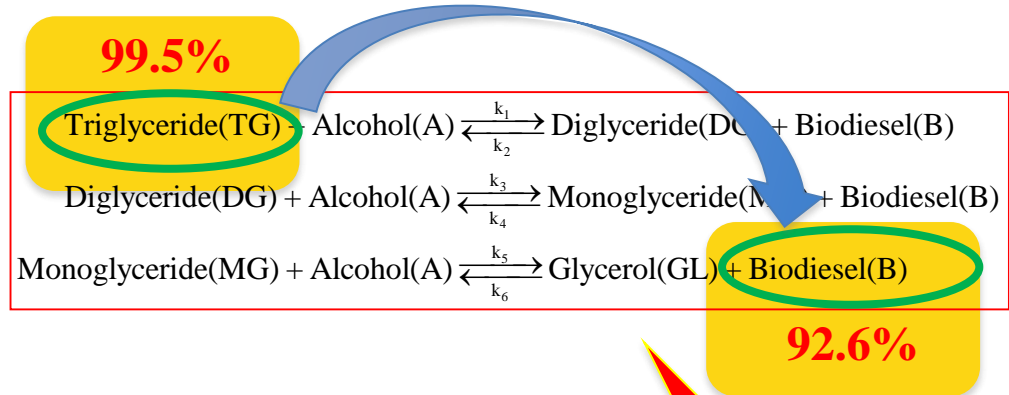
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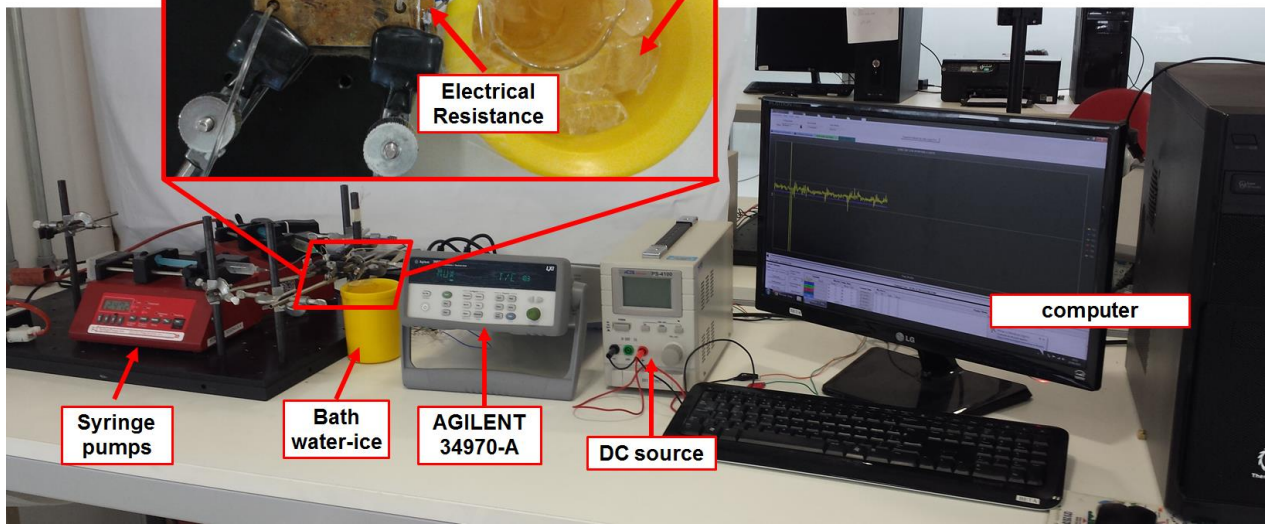
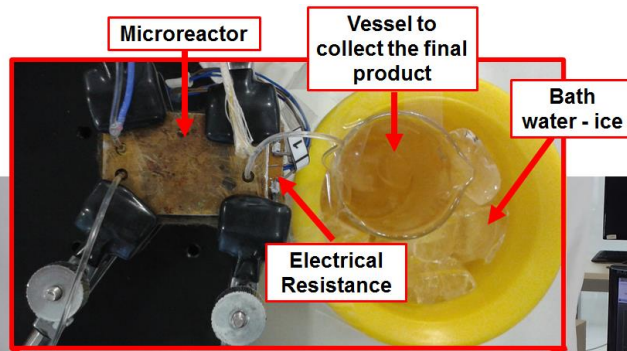
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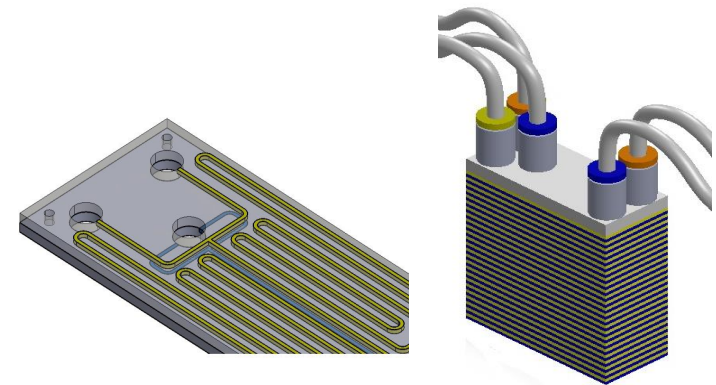
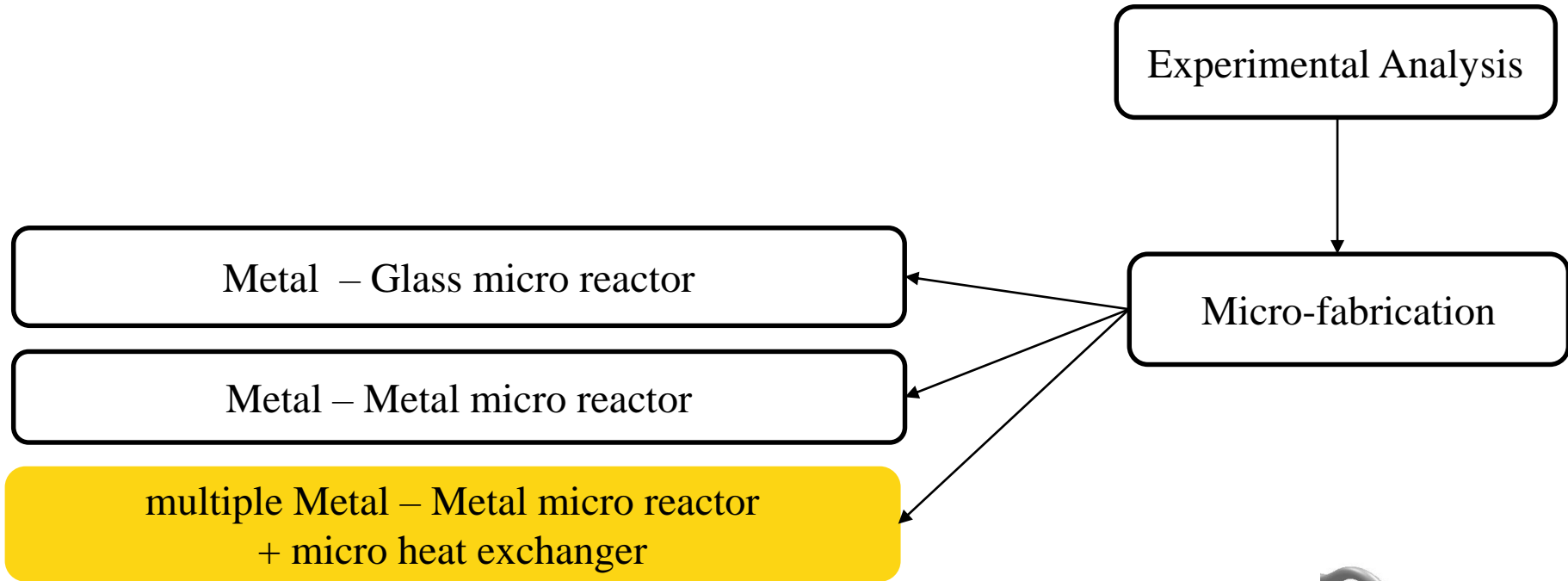


➤ Experimental Setup

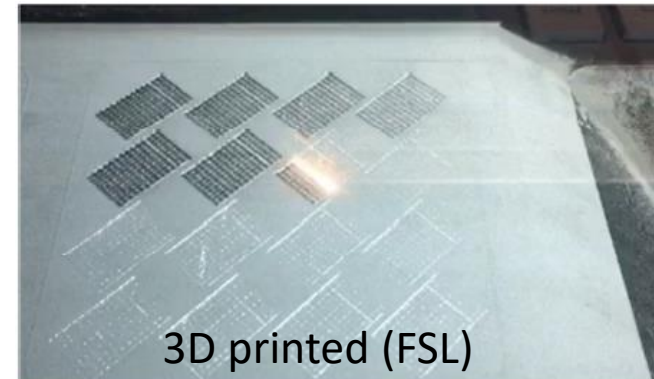
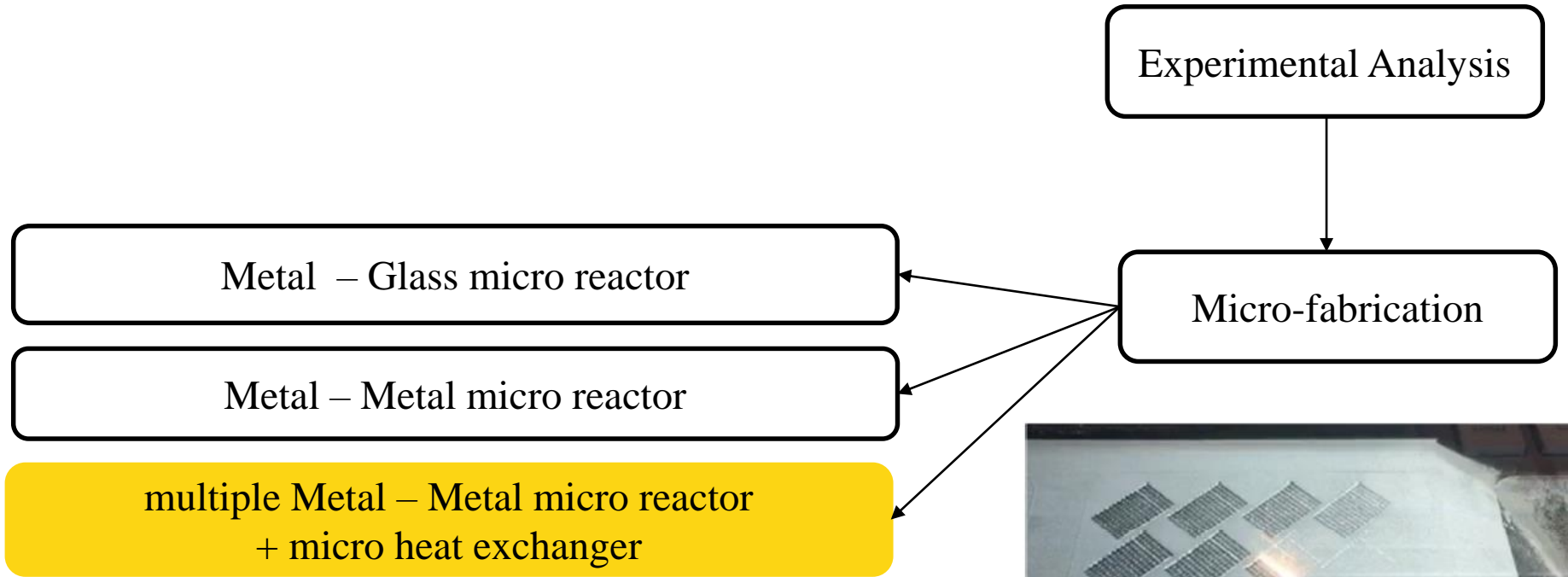


**Gas Chromatography
Analysis
LabCOM/EQ/UFRJ**

R&D Challenges : Biodiesel Production in micro reactors



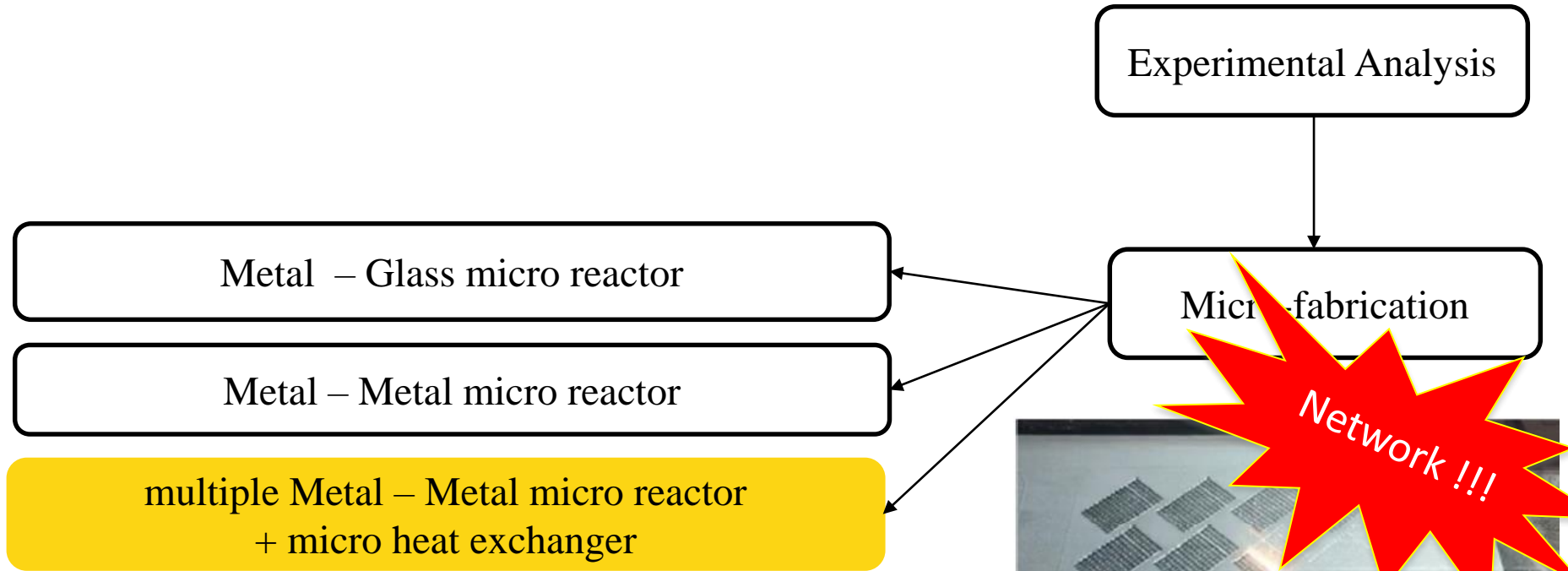
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Features of the Device:

- Composed of **10 micro reactors**
- Composed of **11 micro-heat exchanger**
- Total Dimensions **2,5cm x 4cm x 1.27cm.**
- Microchannels** with square section **400µmX400µm**
- Total Length of the microchannel of the reactor of **43.26 cm.**

R&D Challenges : Biodiesel Production in micro reactors



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- Triglyceride conversion during the **ethanol** transesterification reaction

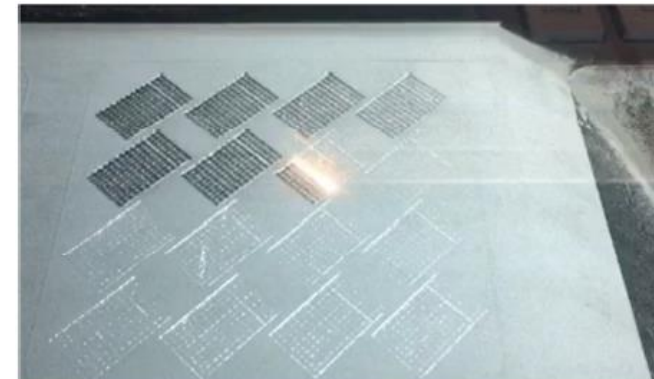
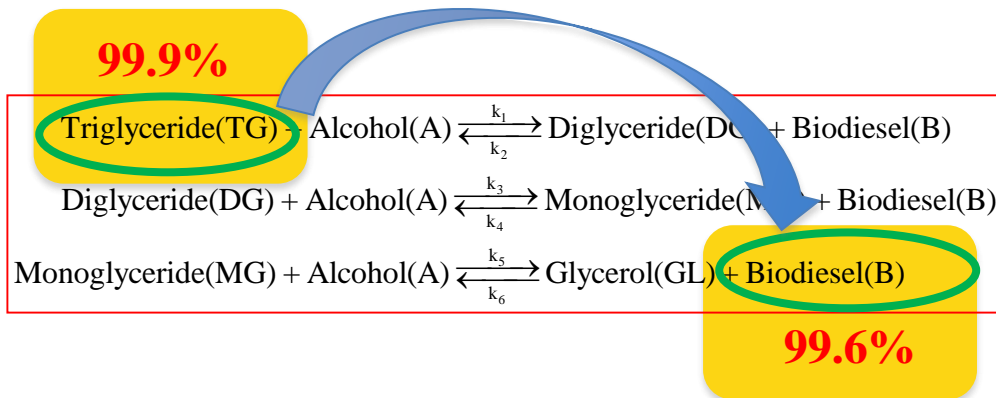
Ethanol/Soybean Oil ratio: **20:1**

Catalyst: NaOH **1,5% wt** oil

Reaction temperature: **64,9° C**

Residence time: 35 seconds

- 3D printed Experimental results



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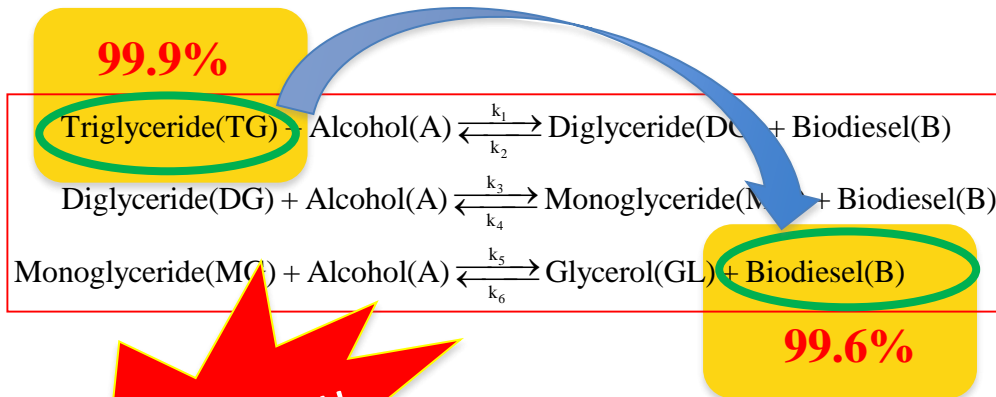
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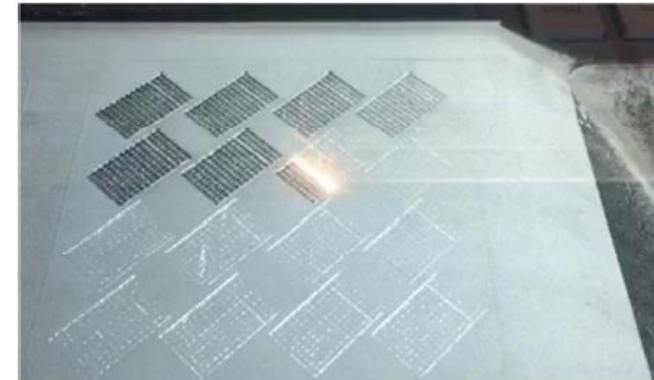
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Network !!!

**Gas Chromatography
Analisis
LabCOM/EQ/UFRJ**



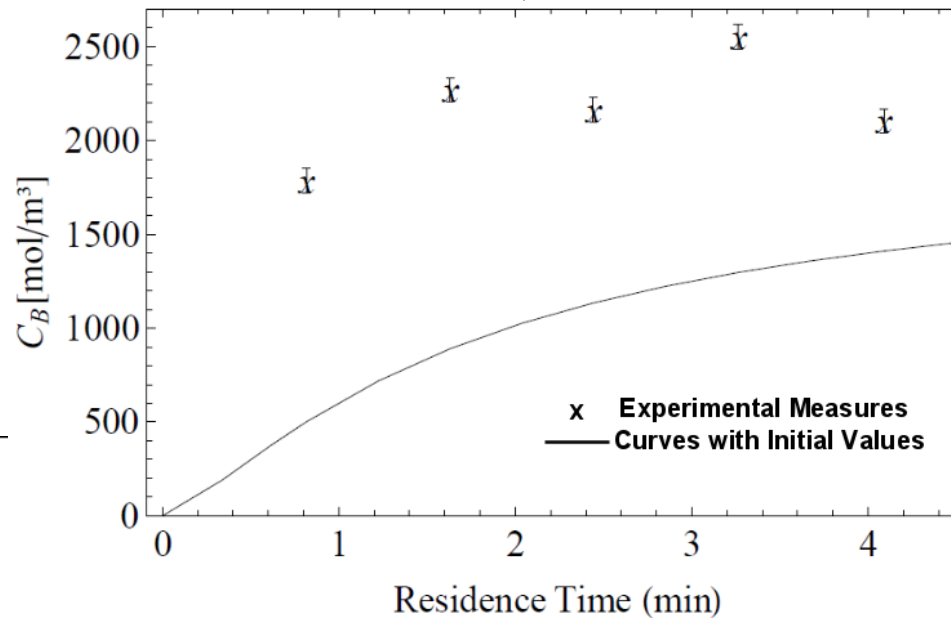
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R&D Challenges : Biodiesel Production in micro reactors

Theoretical Analysis

Experimental Analysis



(Al-Dhubabian 2005)

k_1 [$\text{mol}/(\text{m}^3 \cdot \text{s})$] $4,368 \times 10^{-6}$

k_2 [$\text{mol}/(\text{m}^3 \cdot \text{s})$] $9,623 \times 10^{-6}$

k_3 [$\text{mol}/(\text{m}^3 \cdot \text{s})$] $1,88 \times 10^{-5}$

k_4 [$\text{mol}/(\text{m}^3 \cdot \text{s})$] $1,074 \times 10^{-4}$

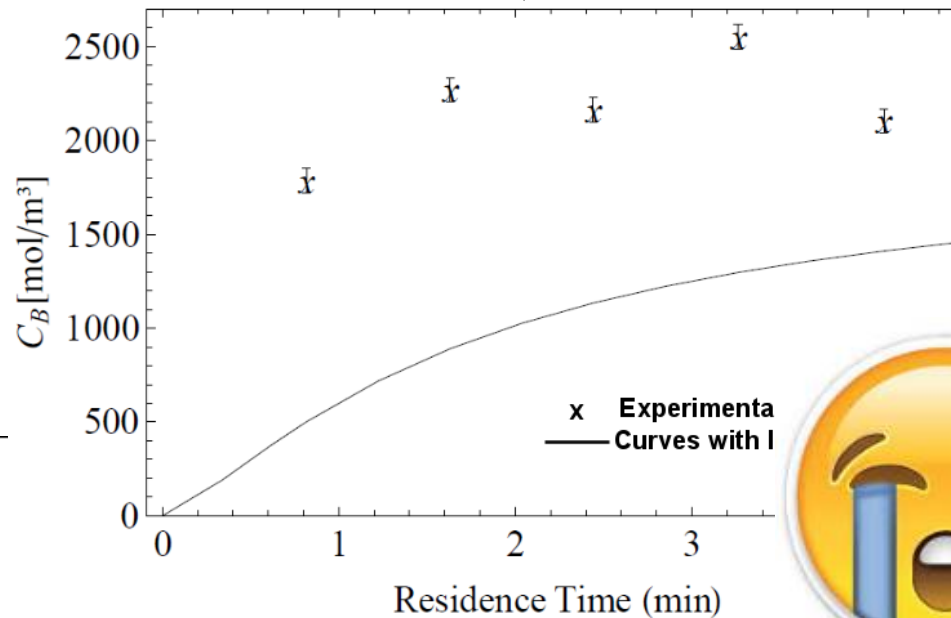
k_5 [$\text{mol}/(\text{m}^3 \cdot \text{s})$] $2,117 \times 10^{-5}$

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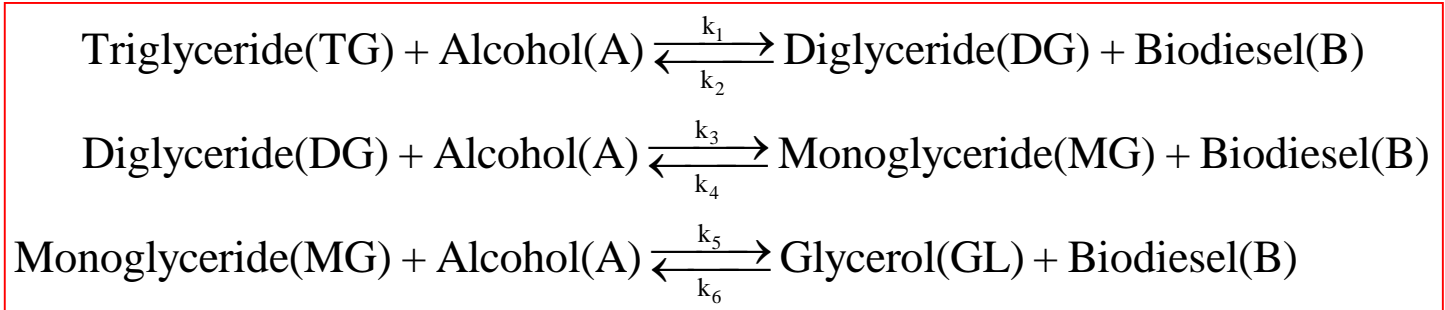
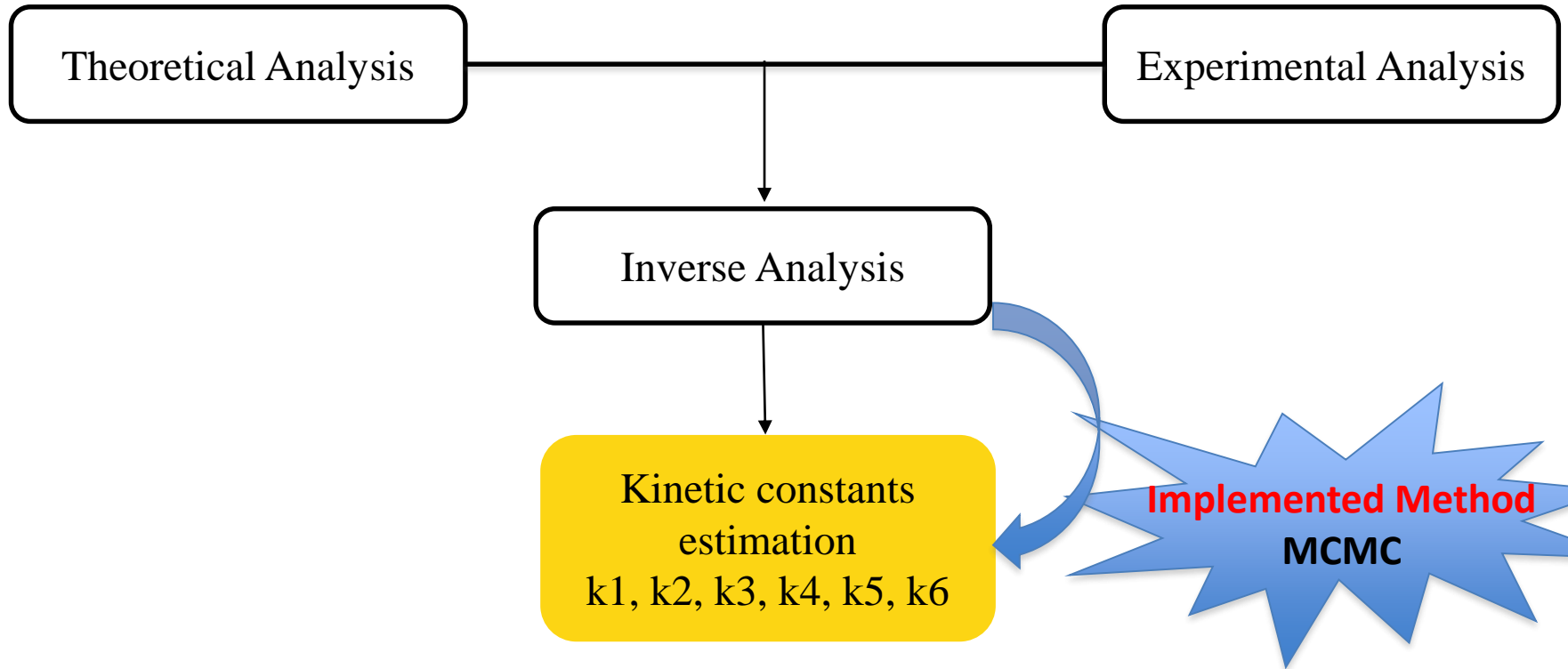
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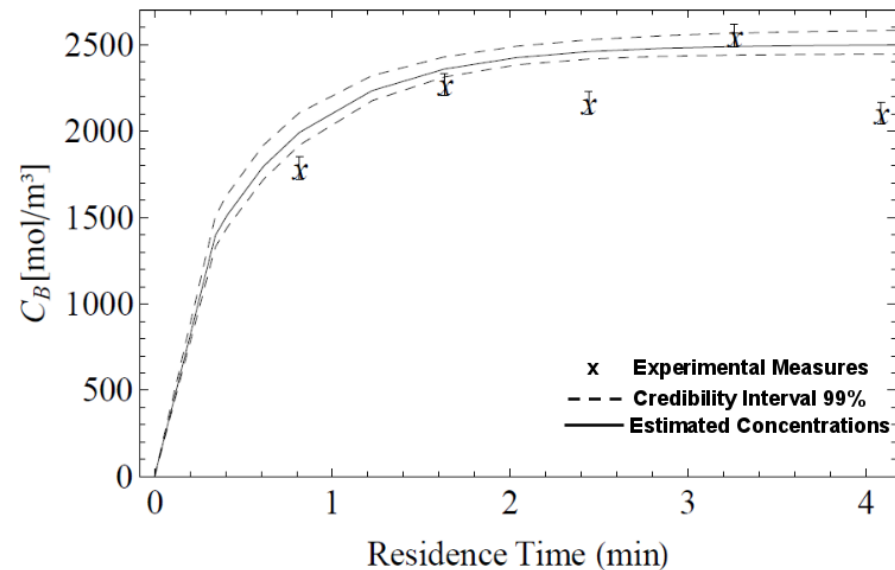
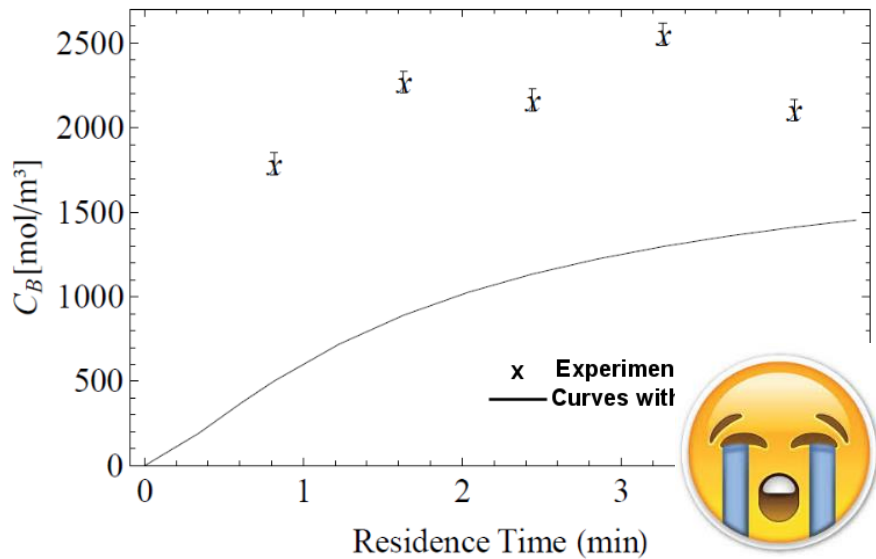
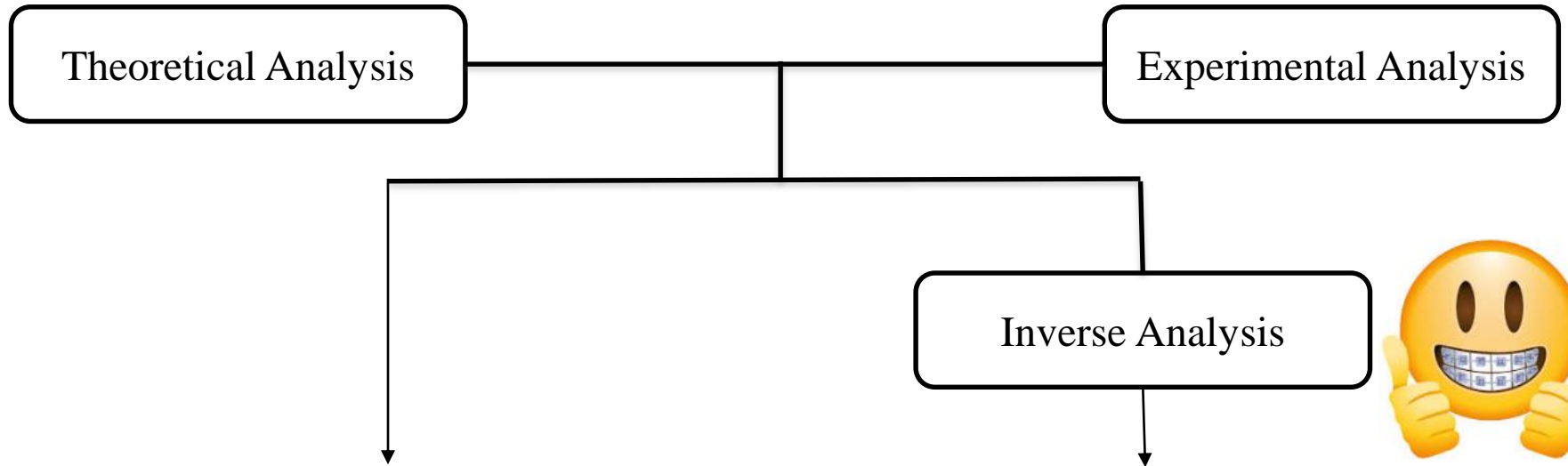
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Validation Experiments



Residence Time	Biodiesel Conc. Experim. Result [mol/m ³]	Biodiesel Conc. Predicted Math. Model [mol/m ³]	Percentage error
0.78 min	2.676,96	2.626,26	2,0%
1.55 min	2.646,54	2.623,22	1,1%

Estimated constant

k_1 0,380

k_2 0,983

k_3 $2,40 \times 10^{-5}$

k_4 $1,62 \times 10^{-5}$

k_5 0,635

k_6 0,038

Estimated biodiesel concentration, based on the estimated kinetic constants, in comparison with two additional cases of residence time.

R&D Challenges : **Biodiesel Production** in microreactors



	Biodiesel Production	Device Total weight	Device Total volume
1 module 10 micro-reactors	1,33 L/day	123 g	2,5cm X 4cm X 1,27cm

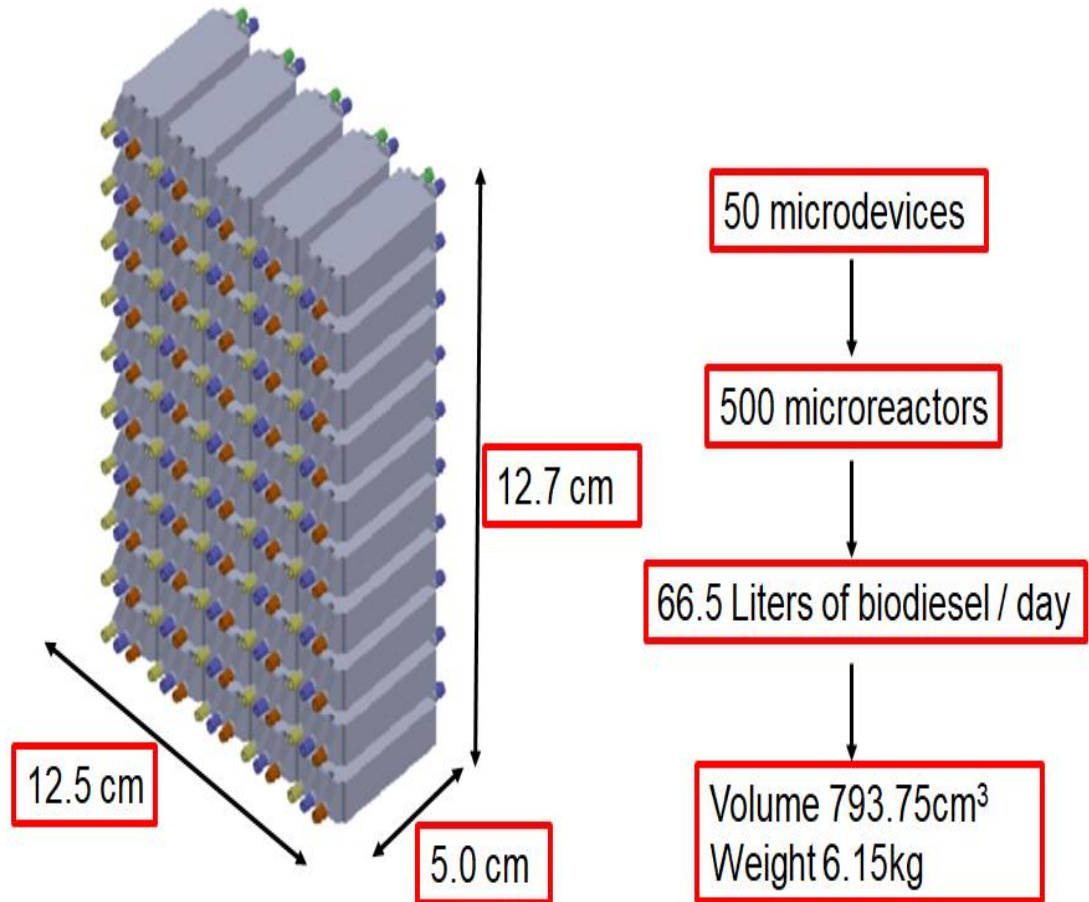
➤ **SCALING UP...**

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➤ **Conclusions**

- Complex physical problem can take advantage of both Computational and Experimental Analysis ;
- Successful fabrication of microreactors – metal/glass and metal/metal and 3D printed
- Estimation of kinetic constants from inverse analysis using real experimental data;
- Demonstration of microreactors for the synthesis of ethanol based biodiesel with promising results (99,61% of biodiesel production in 35 seconds residence time);

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➤ **Future work**

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- Use waste cooking oil in the esterification process in microreactor;

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ACKNOWLEDGEMENT

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Sponsoring Agencies:



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