Microreactor Engineering

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Sweet Spot of Microtechnology

In Affiliation With:

MBI
Microproducts Breakthrough Institute

PTT - LOA
PTT - Laboratories Of America

Microtechnology

The study, development, and application of devices whose operation is based on the scale of 1-100 microns.

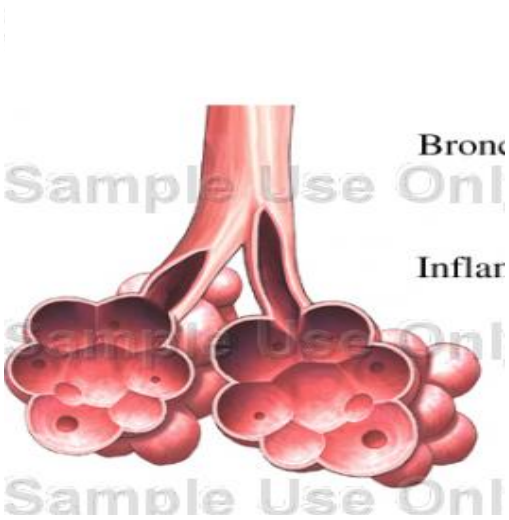
(A human hair is approximately 100 microns thick.

Image source: http://www.flickr.com/photos/thestarshine/69591402/

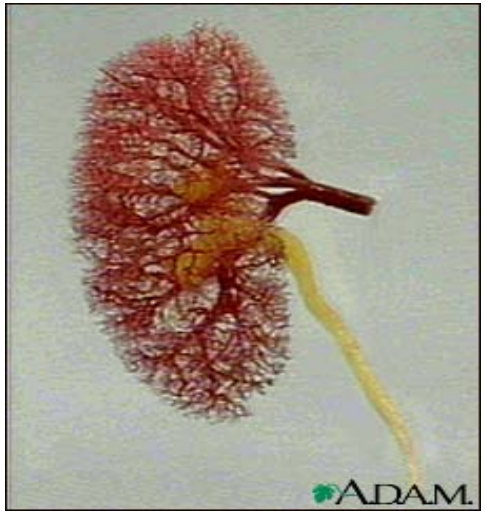
Nature's Microtechnology

Nature has selected the micro scale for the realization of many biological processes.

Leaf



Alveoli



Kidney

What is Microtechnology Good For?

- Production of information

lab-on-chip

- Production of services

pacemaker

kidney dialyser

- Production of energy and bulk material

chemicals

fuels

nanoparticles

Examples of Micro/Nano Technologies Developed In Dr. Jovanovic Laboratory

- Microreactors for Biodiesel Production.
- Microreactors for Production H_2O_2.
- Microreactor for Desulphurization of Fuels.
- Microseparators for Liquid-Liquid Extraction.
- Microreactors for Production of Veins and Arteries.
- Micro Haemo Dialyser.
- Microreactor for Destruction of Toxic Waste.
- Microseparators for Desalination of Water
- Microreactors for Steam Reforming (atm, 1100^{o}C)

Advantages of Microtechnology

- Advantages arising from Fundamental Phenomena;
- Advantages arising from Parallel Architecture;
- Advantages arising from Commercial Applications;
- Advantages in the area of Safety and Security.

Fundamental Advantages of Microtechnology

- **Intensification of Heat and Mass Transport**

- Small scale - Short time of mass and heat transport ($\tau = l^2/D$)

- **Reduced Size**

-10-100 times reduction in hardware volume over conventional technology;
  - 5-50 times reduction in hardware mass;
  - Shifts size-energy trade-offs toward higher efficiency;
  - Able to integrate heat exchanges with reactors and separators simplifying processes.

- **Large surface to volume ratio (10^5-10^8 m^2/m^3)**

- **Changes chemical product distribution**

Fundamental Advantages of Microtechnology

- **Low Pressure Drop**

Reduces power for pumps, fans, and blowers;

- **Gravity independence**

Gravity effect diminish to surface and hydrodynamics forces as size of channels decreases;

- **High Degree of Reaction Control**

Minimizing unwanted environmental and side reactions;

Minimize unwanted reversible reactions;

Enables processing of very energetic reactants;

Intensification of chemical kinetics (*the last frontier in mass transport*)

- **Extremely High Quench Rates**

Small reactant volumes mean less mass or energy required to quench;

Extremely rapid heat transport enables fast thermal discharge.

Advantages of Microtechnology-ParallelArchitecture

- **Fast screening of materials, catalyst and processes**
- **Flexibility in capacity and in design**
  - Provides for deployment at wide range of scales;
  - Facilitates gradual expansion of capacity as scale of operations grows by adding more modules;
- **Operating robustness and controllability**
  - Enhances reliability, allowing problems to be isolated and repaired.
- **Mass Production of Microscale Components**
  - Microlamination process enables mass production;
  - Bonded stacks can contain multiple processes;
  - Multiple processes in a single device reduces field assembly and testing.

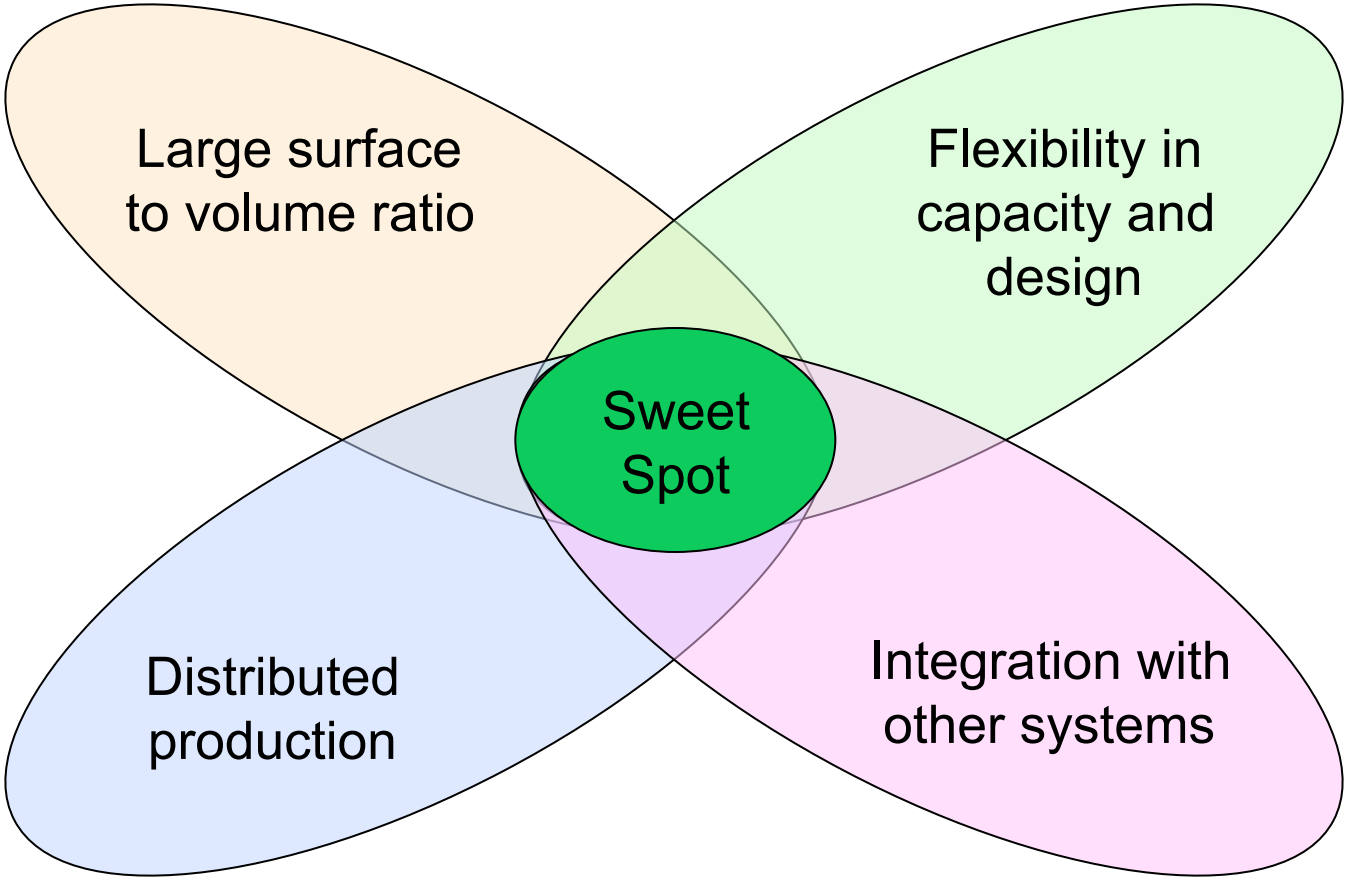
Commercial Advantages of Microtechnology

- **Lower capital investment;**
- **Lower operating cost;**
- **Faster transfer of research to commercial production;**
- **Earlier start of production at lower cost**
  - Reduces life-cycle costs through early testing at implementation scale;
- **Easier scale up (numbering -up) to production capacity;**
- **Distributed technology implementation** (distributed production);
- **Integration of micro-technologies with other systems;**
- **Lower cost of transportation of material and energy;**
- **Replacing batch with continuous processes.**

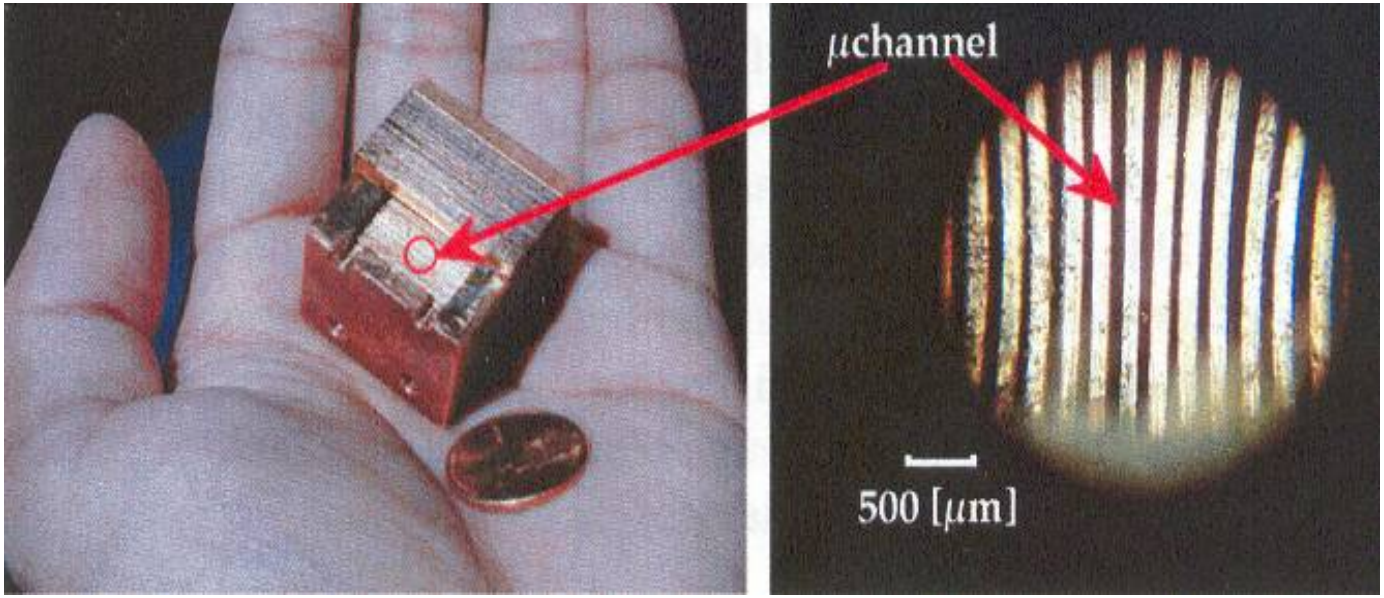
Safety and Security Advantages

- Small channel inhibits flame/explosion front propagation;
- Small volumes translate to low stored energy;
- Smaller volume less hazardous materials in the process.

Sweet Spot of Microtechnology

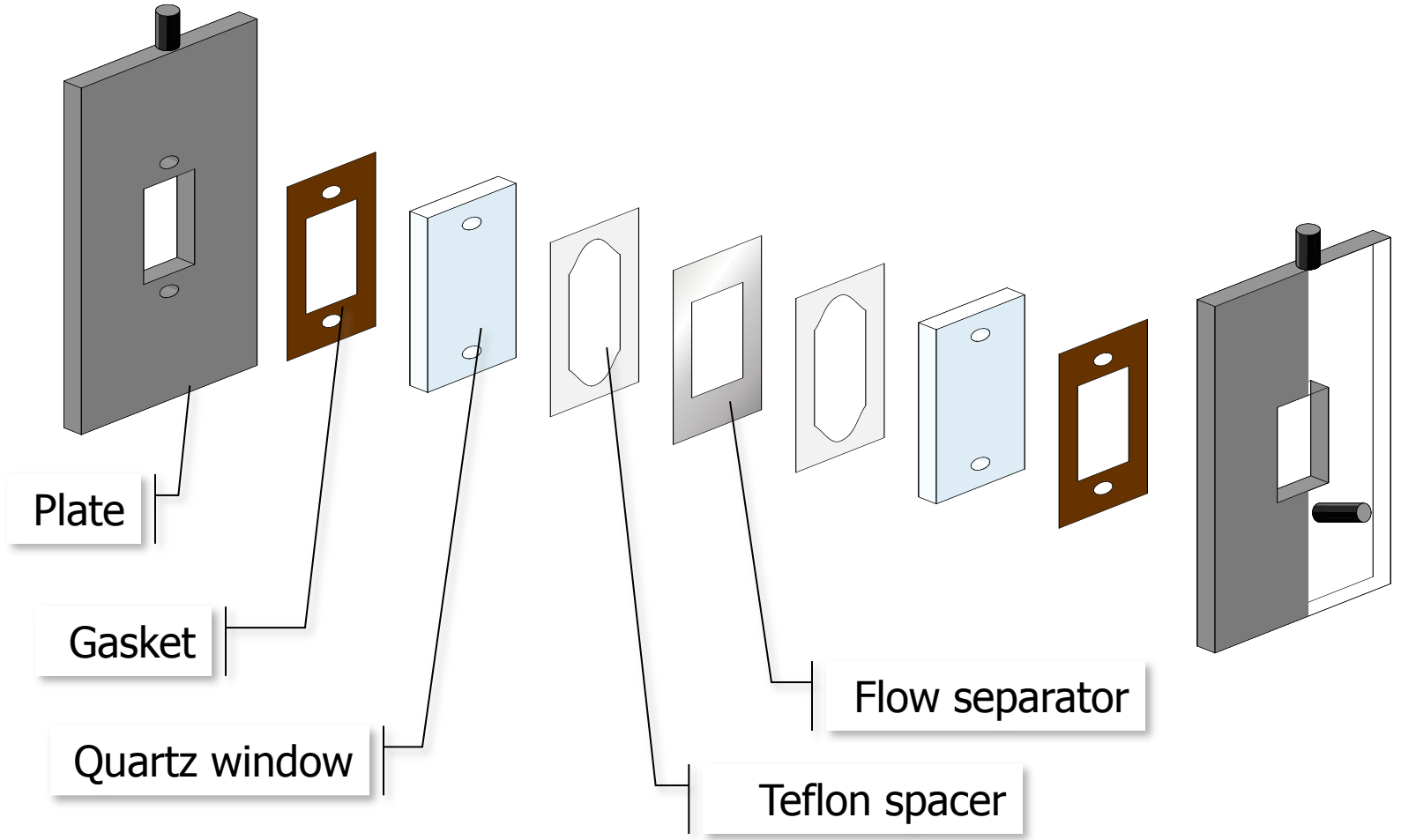


Micro-Scale Reactors

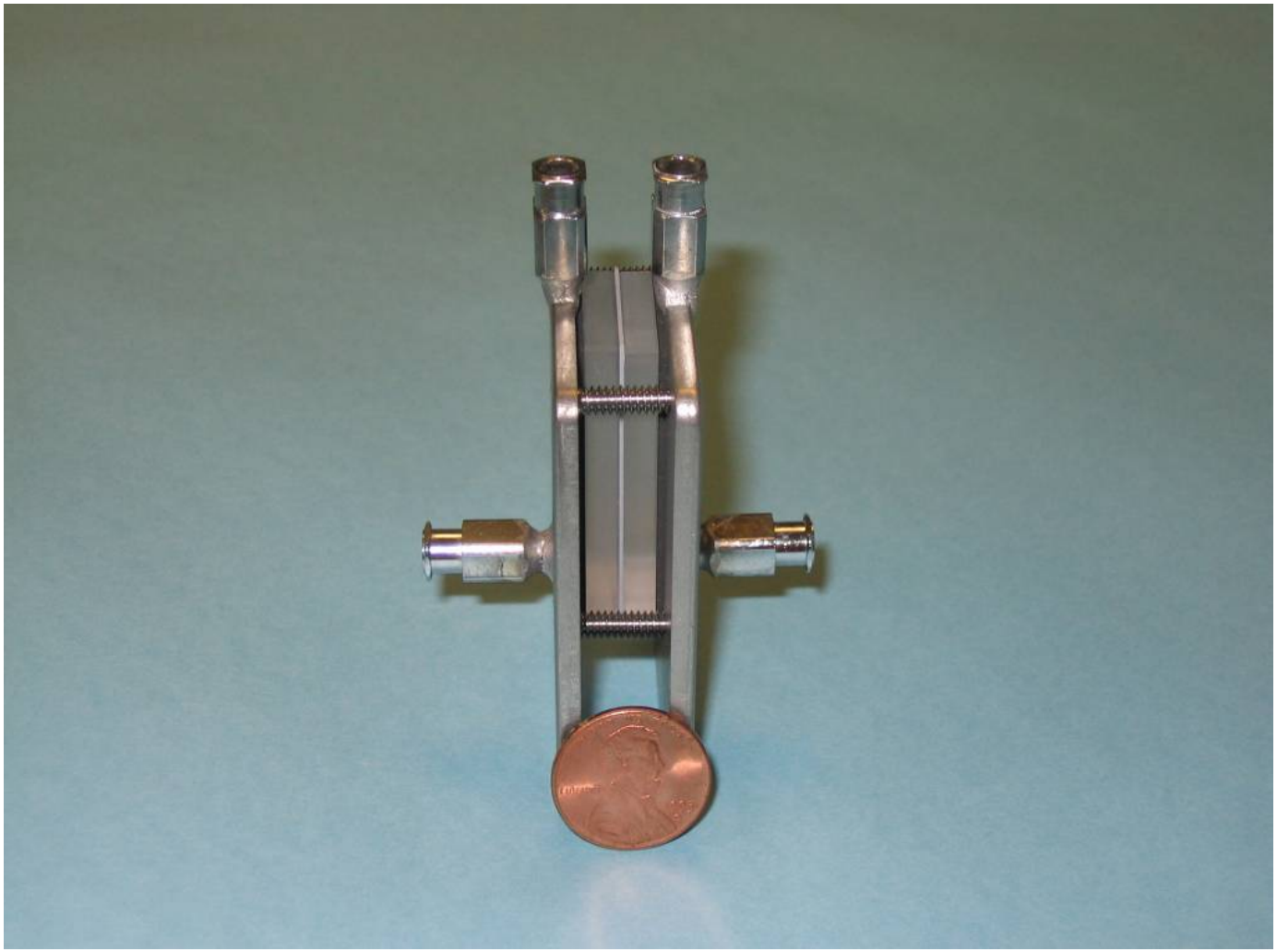


First MECS micro-reactor, OSU 1999

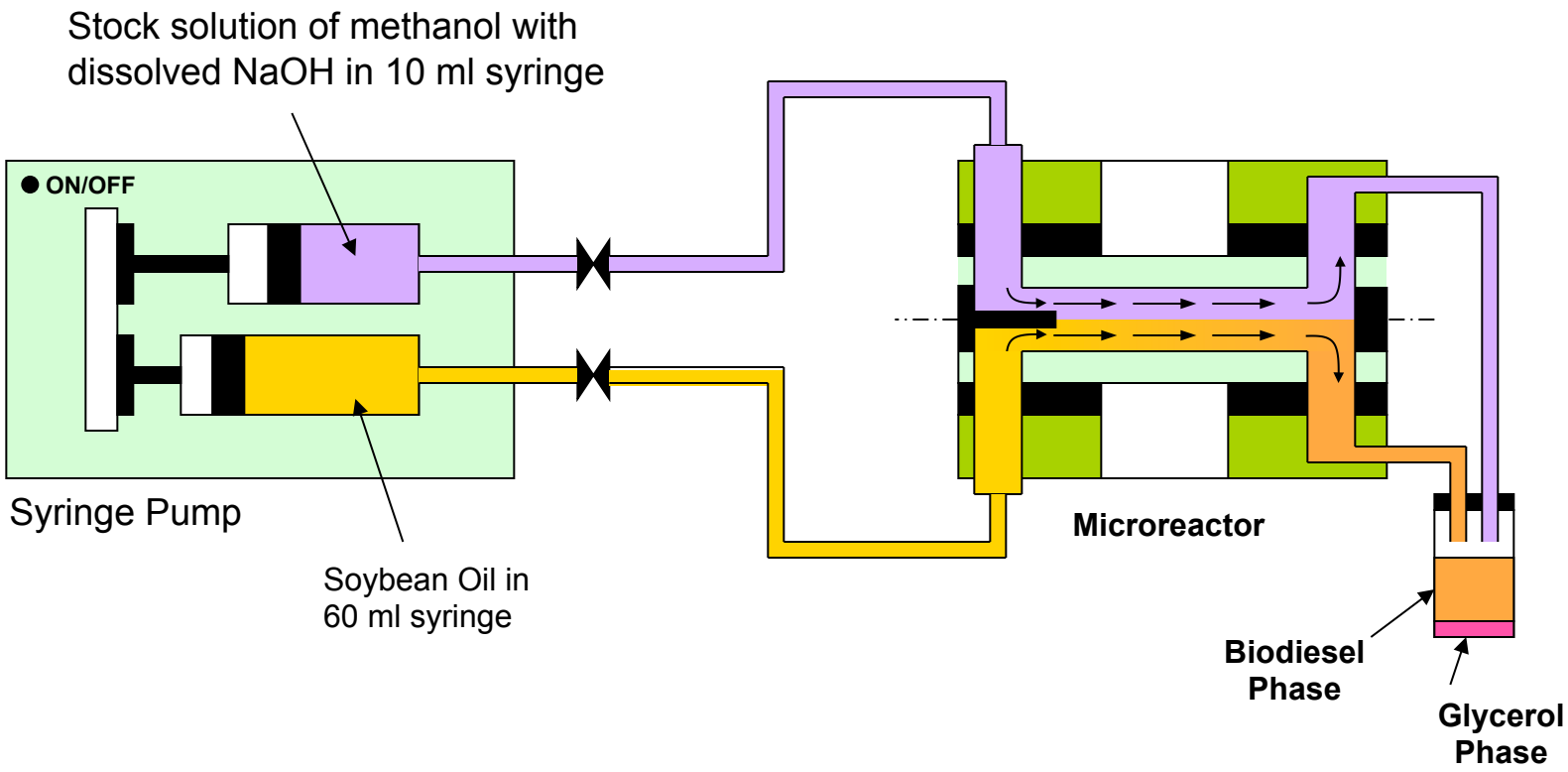
Microreactors



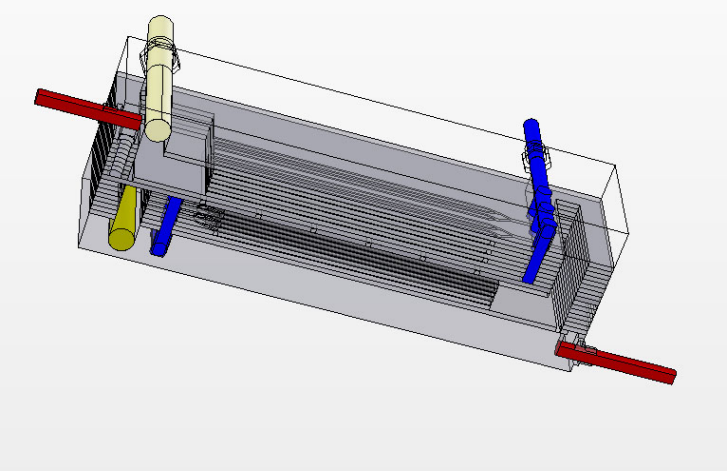
Microreactors

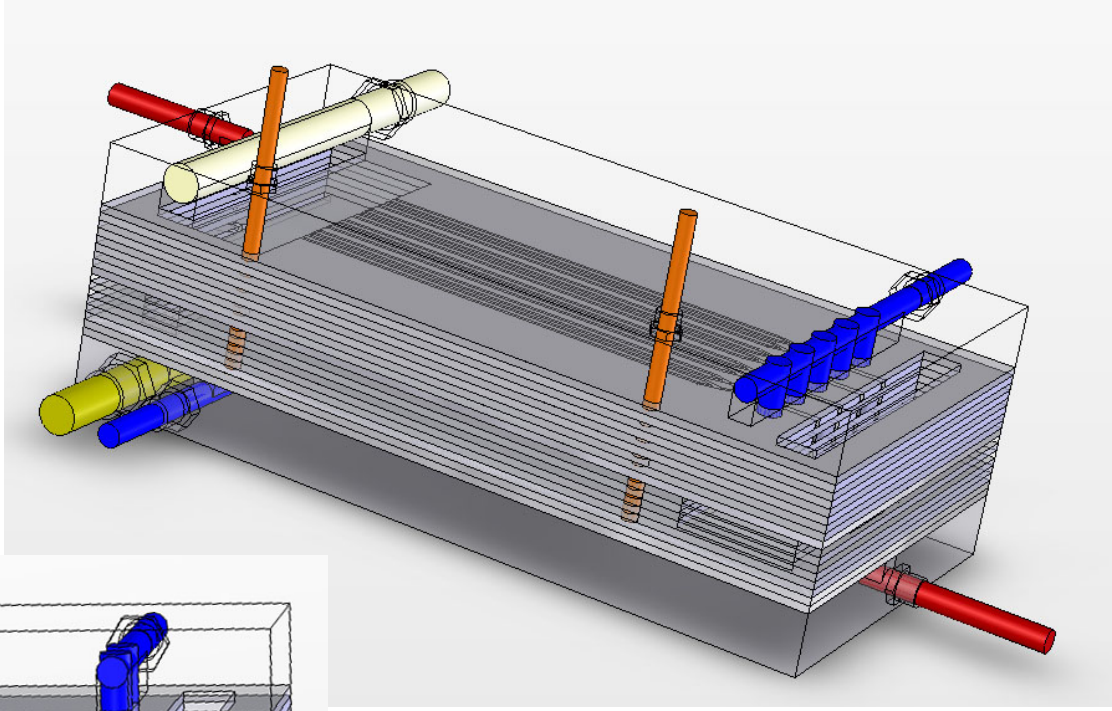


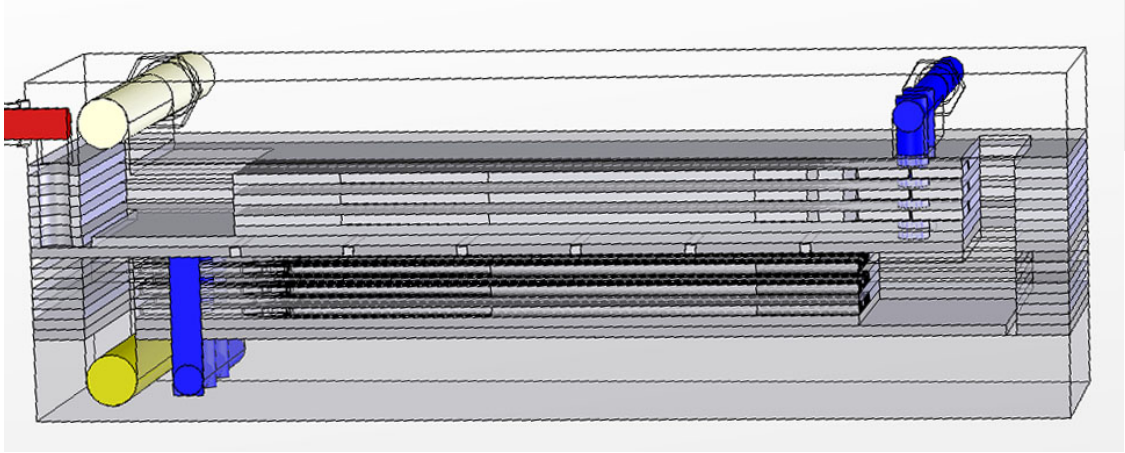
Experimental Setup



Various Views - Biodiesel Microreactor







Biodiesel

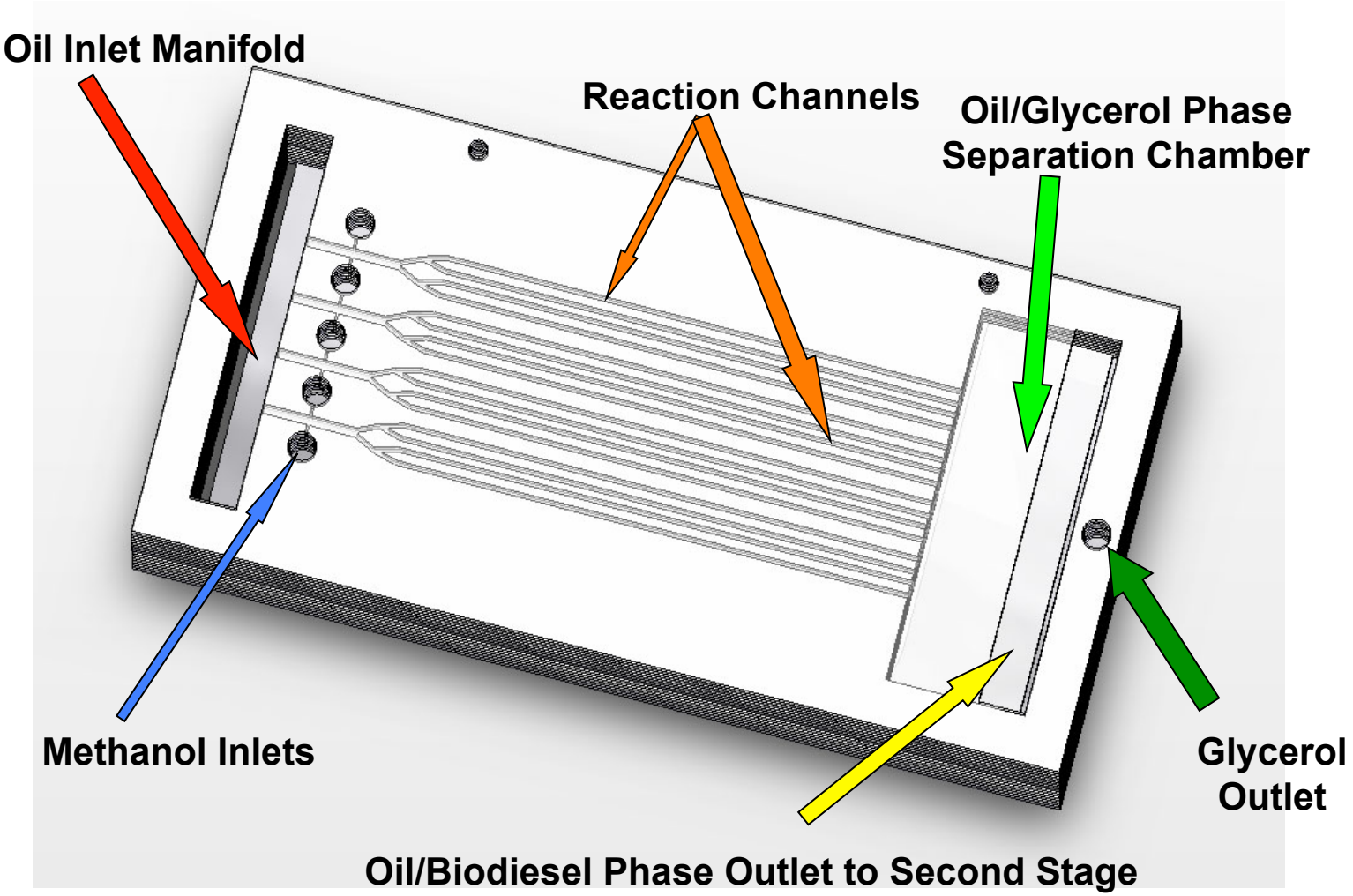
Heating Fluid

Methanol

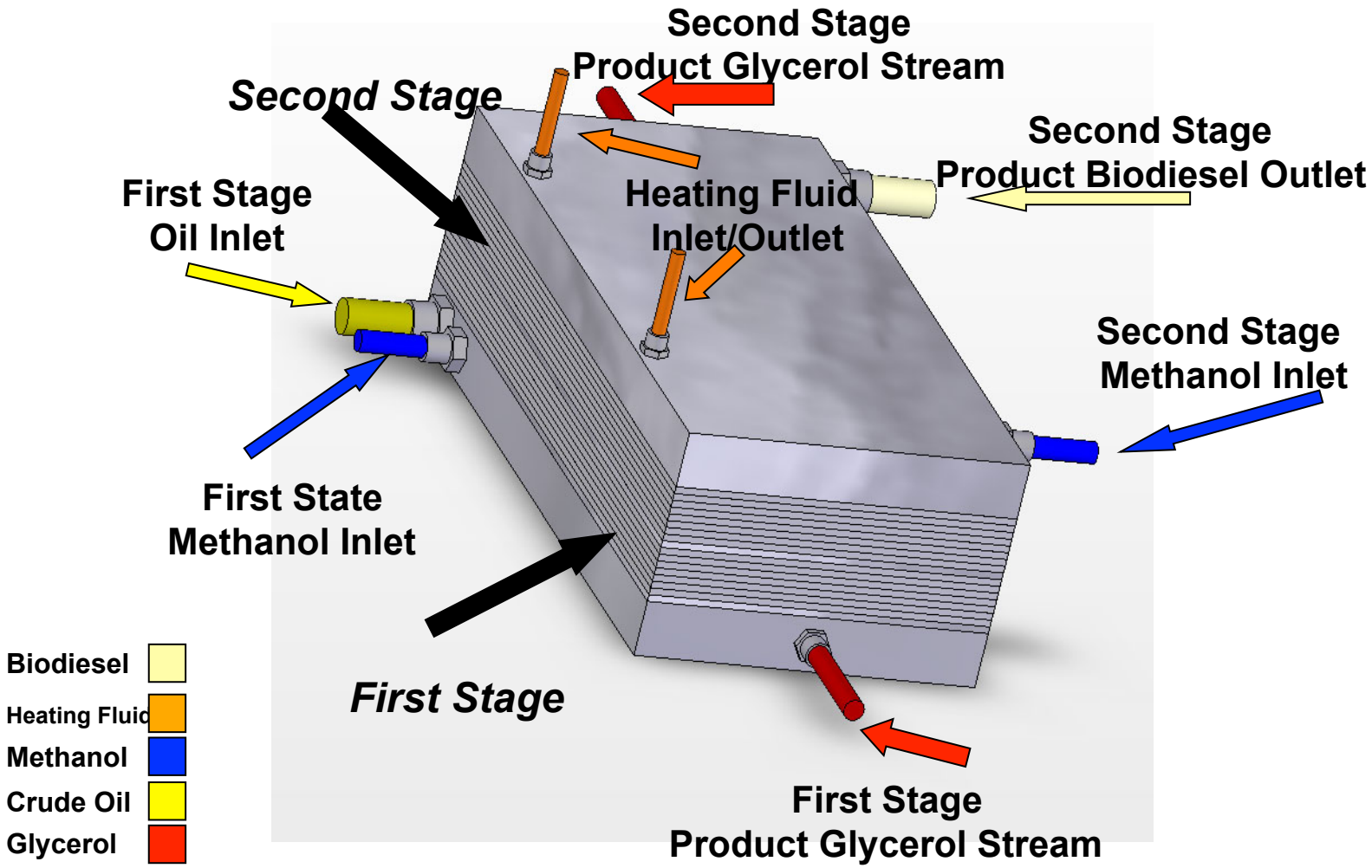
Crude Oil

Glycerol

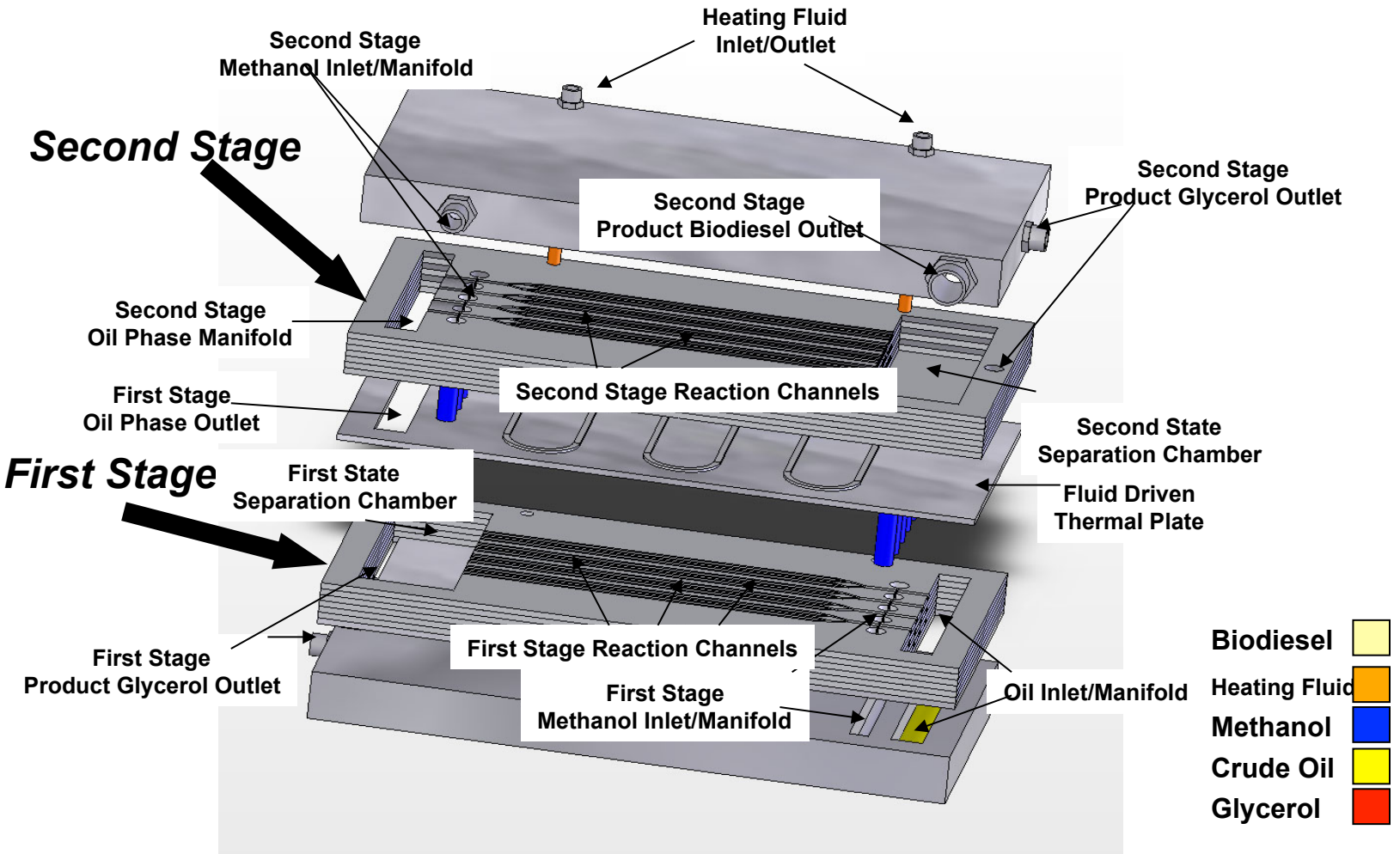
Single Stage Biodiesel Microreactor



Two Stage Biodiesel Microreactor

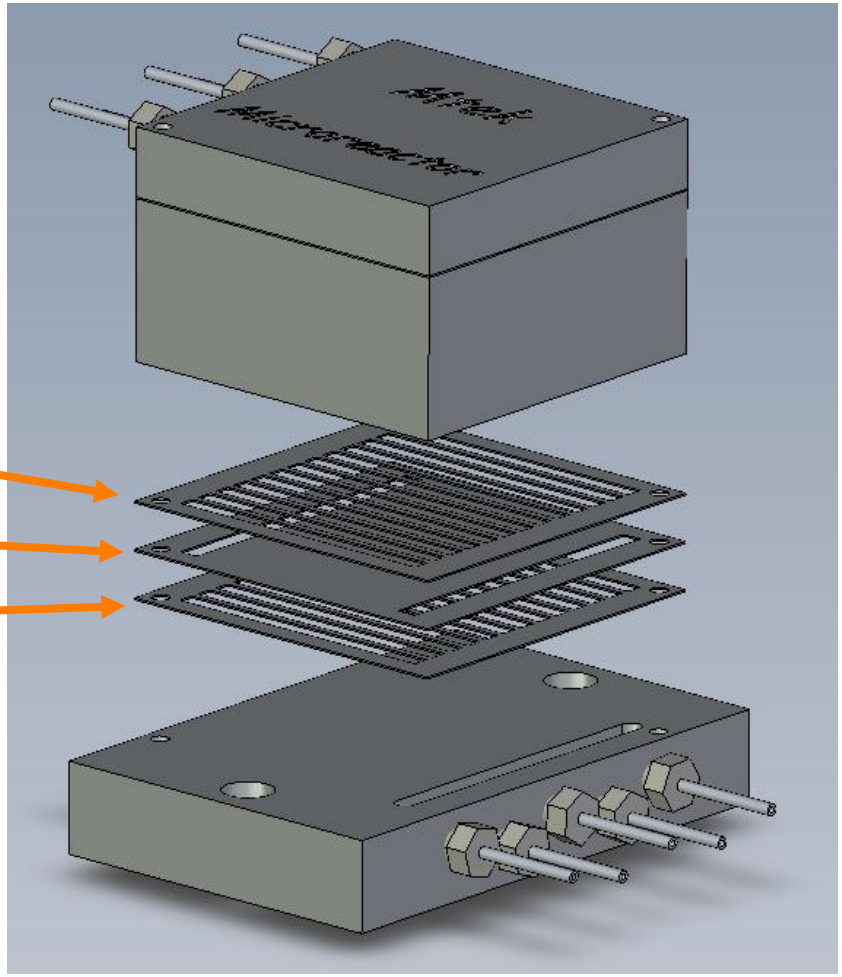


Exploded View - Biodiesel Microreactor



Microreactor Design

Reactor Channels
Separator Plate
Reactor Channels



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People. Ideas. Innovation.

Thank you for your attention!