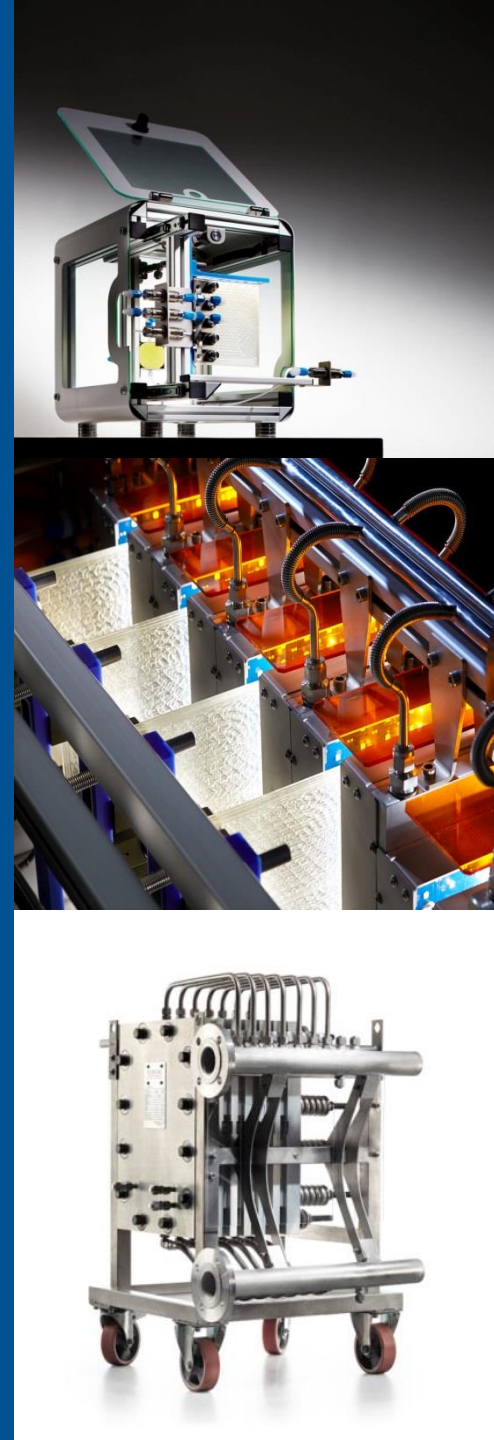


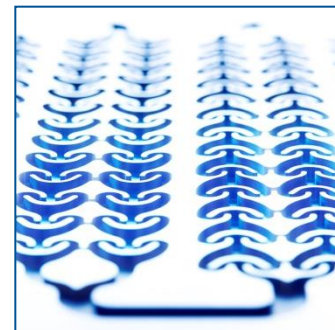
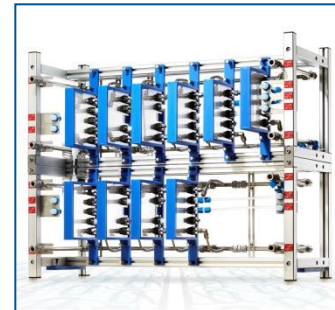
## Flow chemistry and Corning<sup>®</sup> Advanced-Flow<sup>™</sup> Lab Reactor

January 2017



## Agenda

- The Flow Chemistry
- Corning® Advanced-Flow™ Reactor technology
- The Corning® Lab Reactor
- Photochemistry
- Your next step in flow chemistry



## What is flow chemistry

---

- A chemical reaction run continuously rather than in batch
- Standard process for large scale production, only recently implemented for the laboratory and the production of fine chemicals
- It often involves Microreactors

Founded:  
**1851**

Headquarters:  
**Corning, New York**

Employees:  
**45,000 worldwide**

2016 Core Sales:  
**\$9.7 billion**

Fortune 500 Ranking (2017):  
**298**

Corning Incorporated is one of the world's leading innovators in materials science. For more than 165 years, Corning has applied its unparalleled expertise in glass science, ceramics, and optical physics to develop products and processes that have transformed industries and enhanced people's lives.

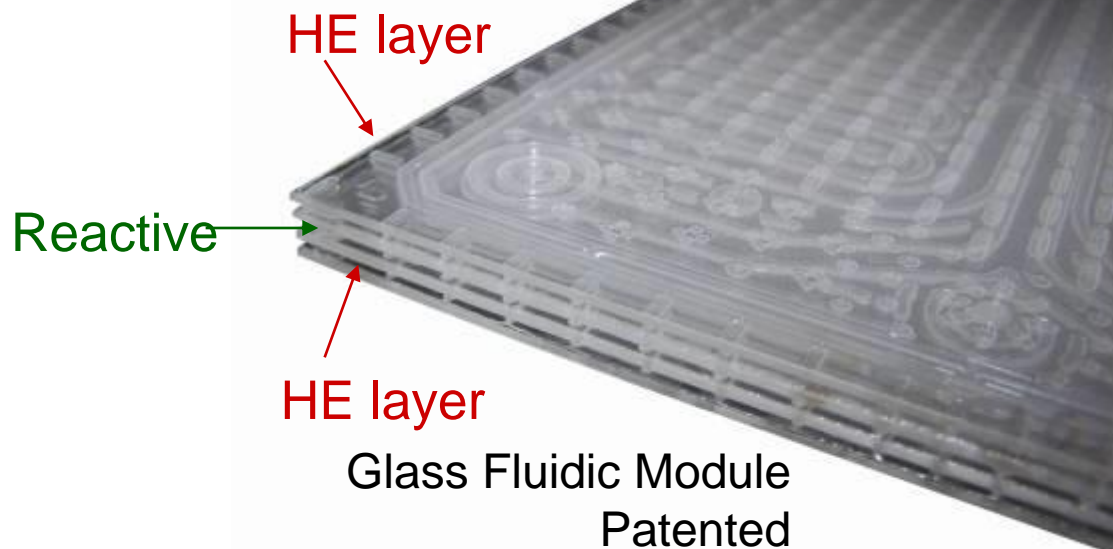
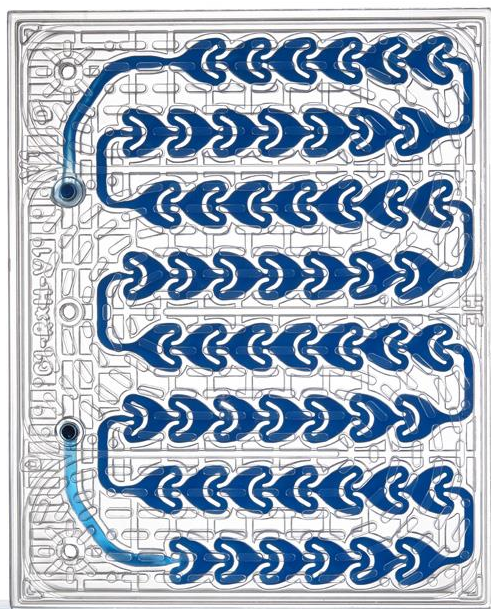
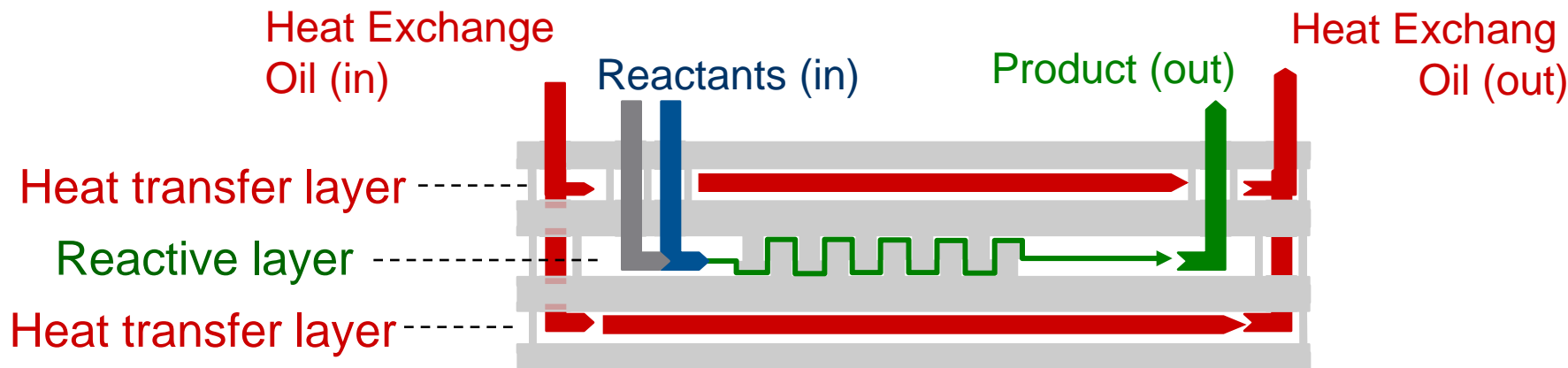




CORNING<sup>®</sup> ADVANCED-FLOW<sup>™</sup> REACTORS

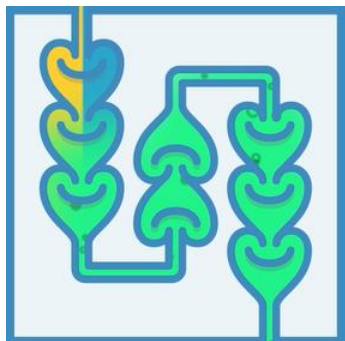
## Corning<sup>®</sup> Advanced-Flow<sup>™</sup> Reactor Technology

# Fluidic module designs: for superior mass transfer and heat exchange

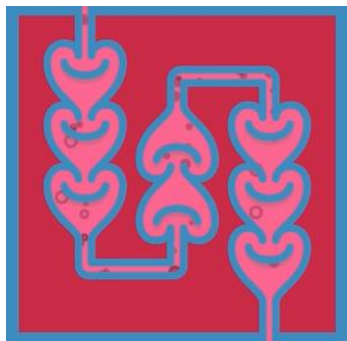


## Corning® AFR™: unique concepts and advantages

### High Mixing



### High Heat Exchange



### Materials



### Seamless Scale-Up



### Complete units



**HEART patented shape**

**Ideally for immiscible and multiphase systems**

**Combined heat exchange and reactive path in a sandwich structure**

**Independent thermal control**

**Glass and Ceramic**

**Superior corrosion resistance**

**Reactors designed for seamless scale-up**

**Direct from Lab to Production**

**Complete turn-key solutions**

**Engineered and customized units**



## CORNING® ADVANCED-FLOW™ REACTORS

**100X** BETTER MIXING

**1000X** HIGHER VOLUMETRIC HEAT TRANSFER

**1000X** LESS MATERIAL INVENTORY

**Advanced-Flow™ Reactor Technologies:**  
Ensure superior mass & heat transfer, enabling excellent  
process intensification



## Batch versus Continuous Flow



6000 L reactor  
5000L Liquid Holdup



G4 reactor  
5L Liquid Holdup



# Corning® Advanced-Flow™ Reactor Value Proposition

## Revolutionary Improvement vs. Batch



CORNING<sup>®</sup> ADVANCED-FLOW<sup>™</sup> REACTORS

## Laboratory work with Corning<sup>®</sup> Low-Flow and Lab Reactor

# What is AFR<sup>®</sup> Lab Reactor ?

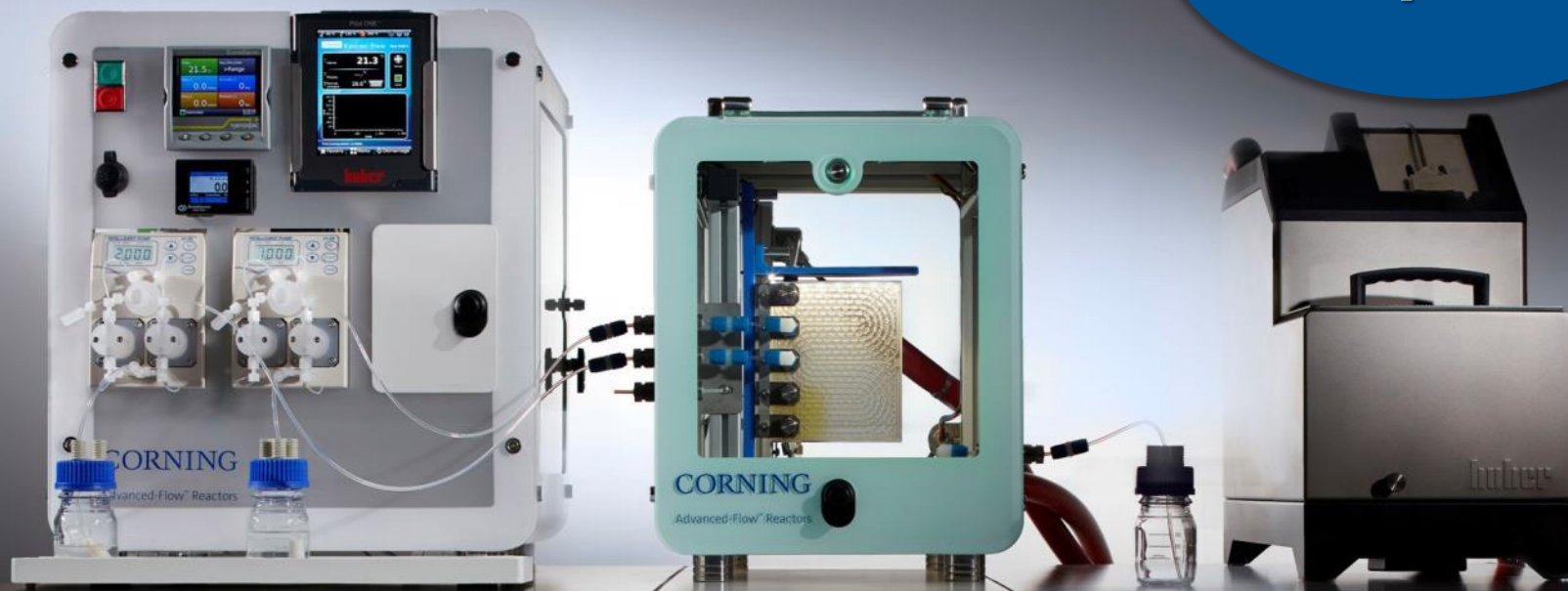


A complete **Plug  
and Play Lab  
System**

(reactor + auxiliaries)

**Ready to start  
& easy to use**

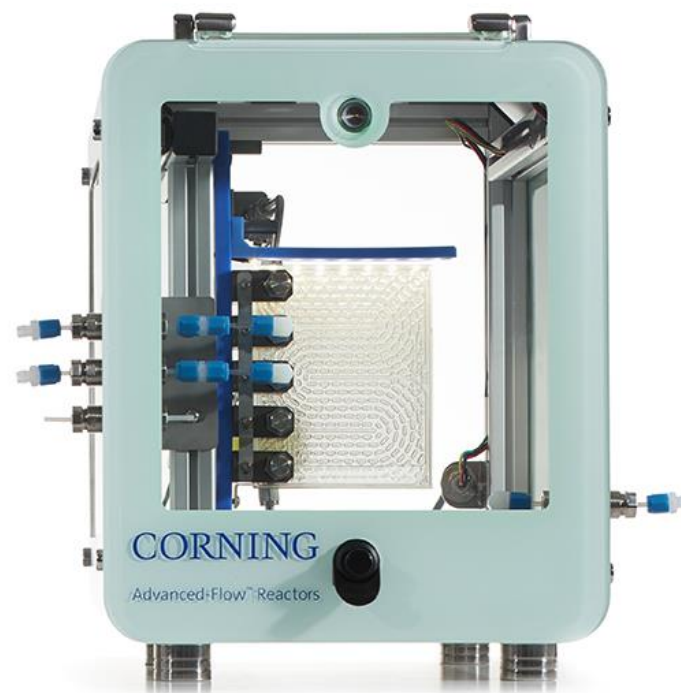
Being **seamless  
scalable with  
AFR<sup>®</sup> products**





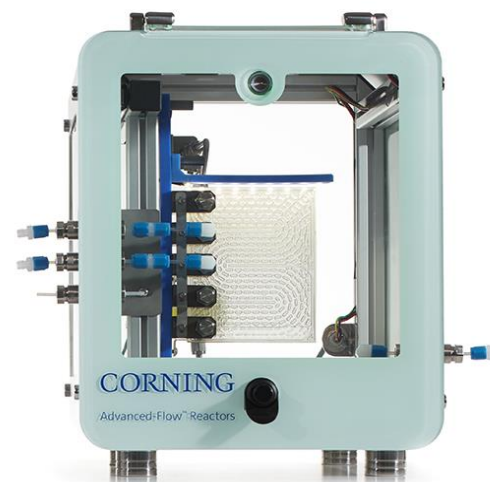
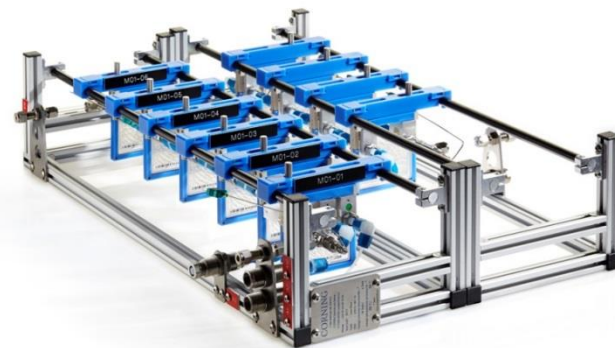
## Lab Reactor reaction module: Key features

- Up to 2 G1 LF glass fluidic modules
- Outstanding mixing and heat exchange with **patented HEART design**
- **Low internal volume** : 2,5 ml per fluidic module
- **Seamless scale-up with other AFR<sup>®</sup> products**
- **Back pressure regulator** for pressure control integrated
- T° measurement
- Full metal free system

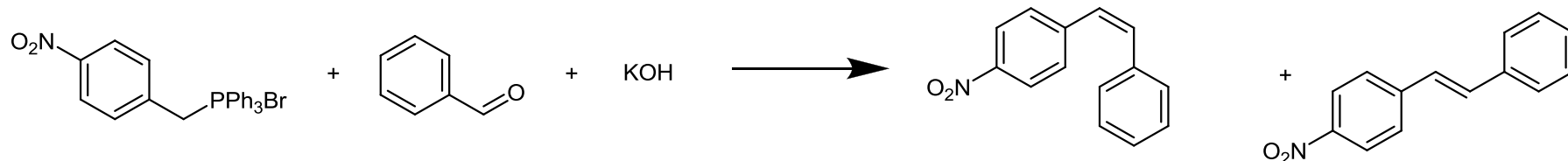


## Why to use it at Lab scale?



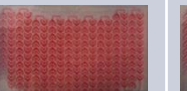
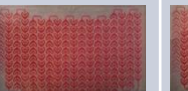


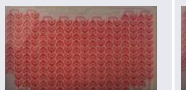
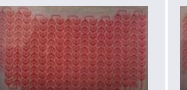
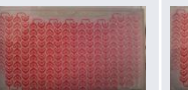
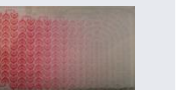
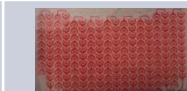



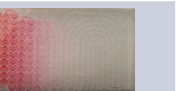


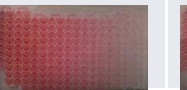

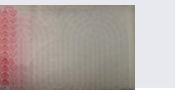




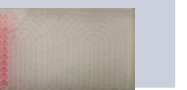
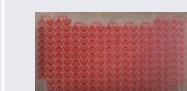
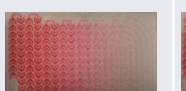




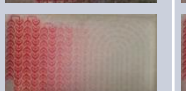


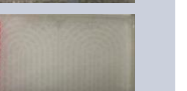
- Numerous parameters to test
- Small volume of reagents
- Quick results required
- Extremely broad chemical conditions
- Broad range of temperature
- Scalable conditions
- Corrosive conditions
- Exothermic Reactions



## Screening of reaction time and temperature



- Wittig reaction
- Quick screening of reaction conditions
- High mass transfer allow to work with multi-phasic conditions

	8 ml/min	4 ml/min	2 ml/min	1 ml/min	0.5 ml/min
20 °C					
30 °C					
40 °C					
50 °C					
60 °C					
70 °C					
80 °C					
	20.3 s	40.5 s	81 s	162 s	324 s

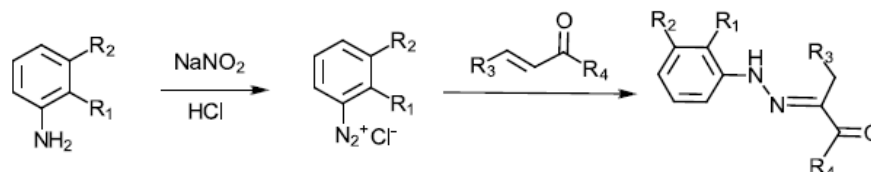
## Customer case

### Medichem

#### Context

##### *Diazotization*

*Risk of precipitation of a shock sensitive intermediate*



#### Step 1

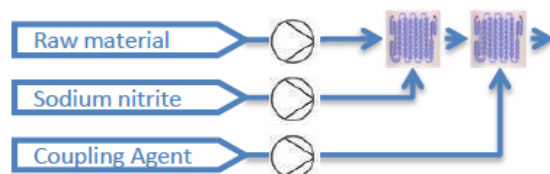
Preliminary tests in flow at lab scale (g/min) using Low Flow reactor

*Improved yield, precipitation is avoided*

#### Step 2

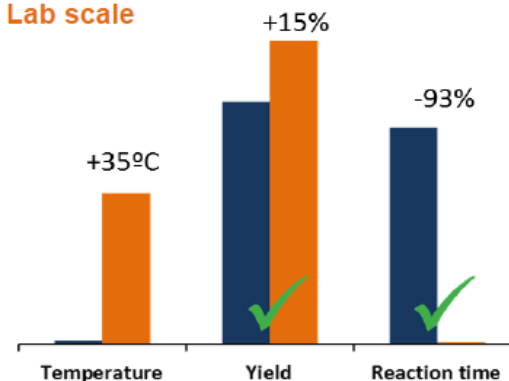
Scale-up to kilo lab: scale-up factor 18

*Planned by end of this year*

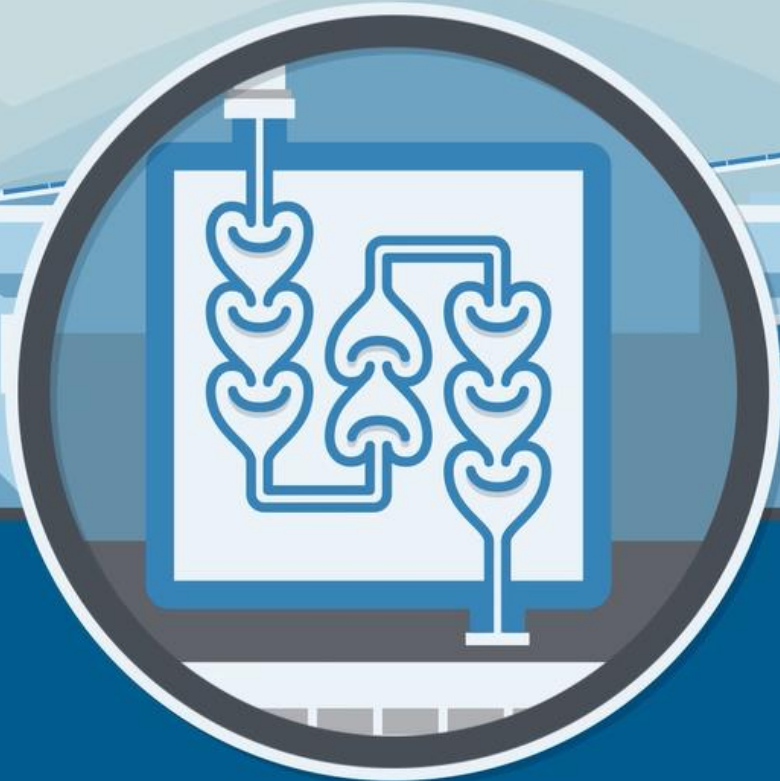


Batch

Flow Lab scale





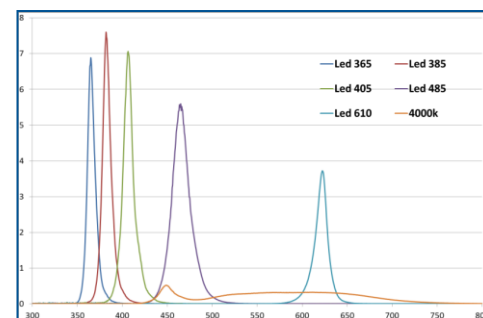


CORNING® ADVANCED-FLOW™ REACTORS

## The Photochemistry with the Lab Photoreactor

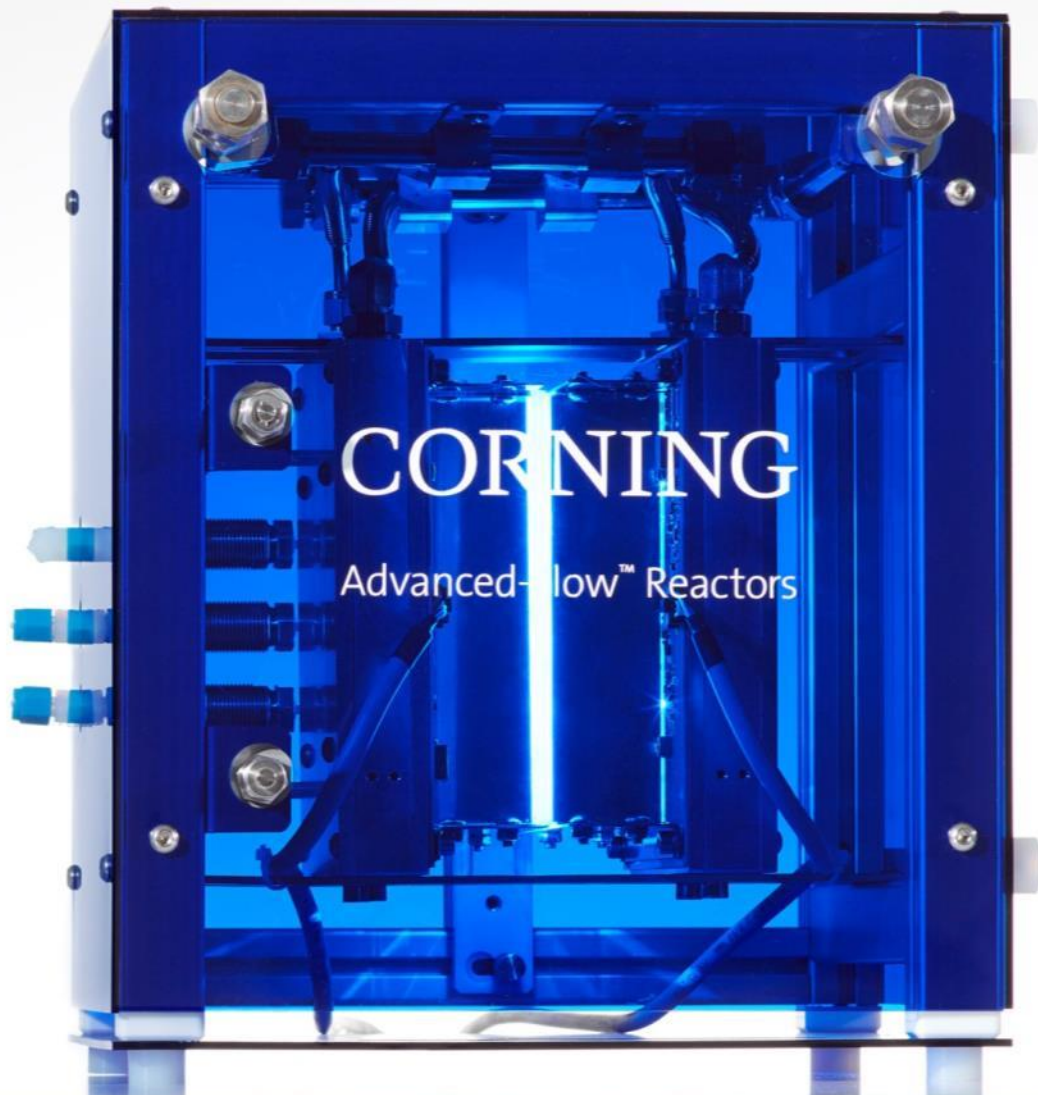
## Photochemistry

- Unique combinaison of Corning Advanced-Flow Reactors with highly engineered LED lightning modules
- Start-up kit: the Lab Photo Reactor
  - 6 different wavelength
  - Wireless intensity control
  - Small internal volume
- Production in G1 Reactor and possibility to move to even larger scale

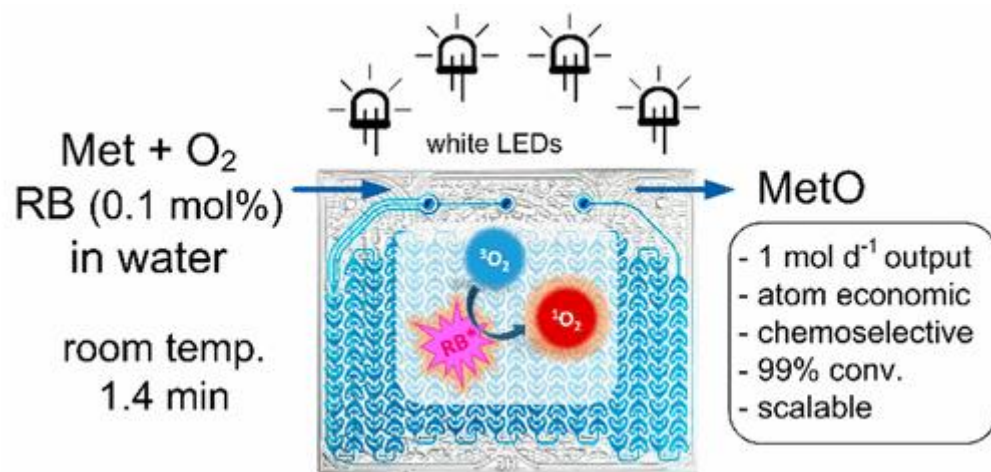


# Lab Photo Reactor module : Key features

- **1 G1 LF** fluidic module illuminated from both sides by **2 LED arrays**
- Multi-wavelength tunable LED irradiation source (**6 different wavelengths**)
- **Wireless control** of wavelength selection and intensity

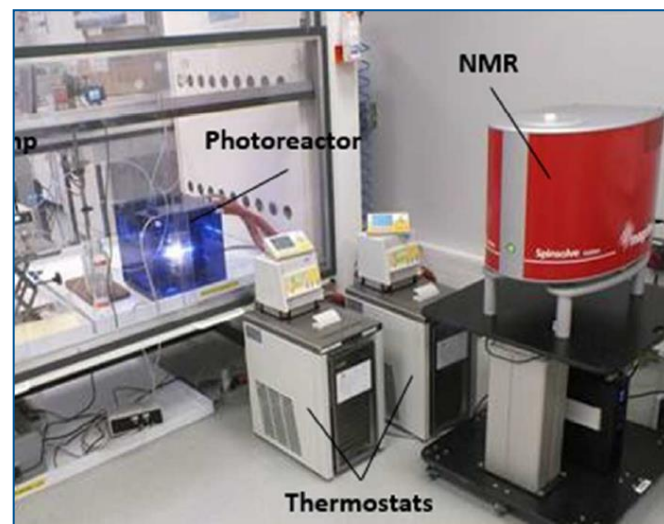
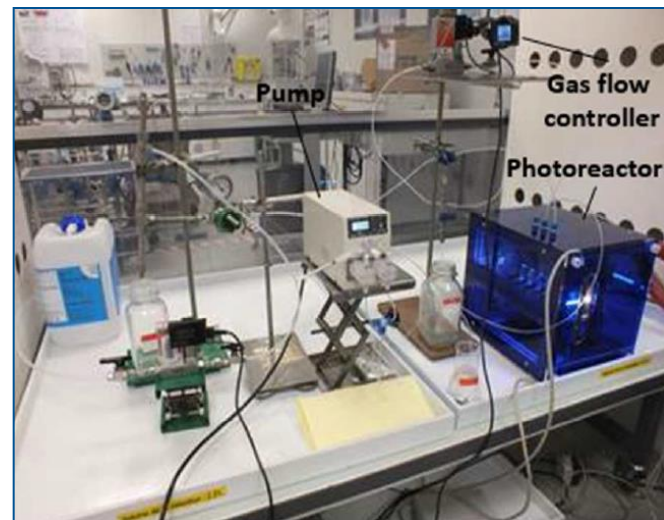


## Exemple: Methionine oxidation



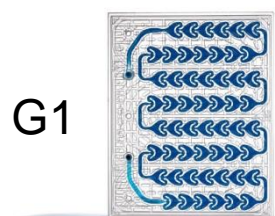
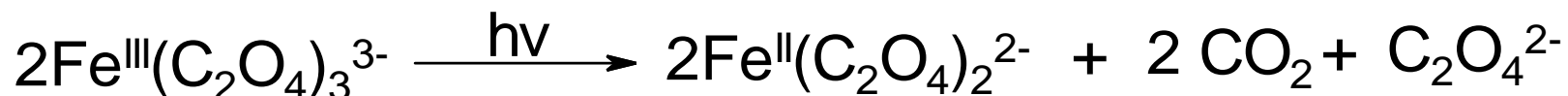
- Sustainable process engineering
- No waste generation
- Safe operating conditions

*Org. Process Res. Dev.*, 2017, 21 (9), pp 1435–1438





## Characterization with Actinometer



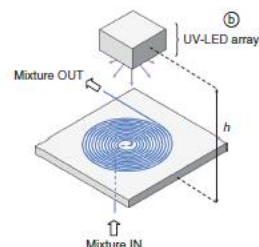
G1

V= 8 ml



G3

V= 60 ml

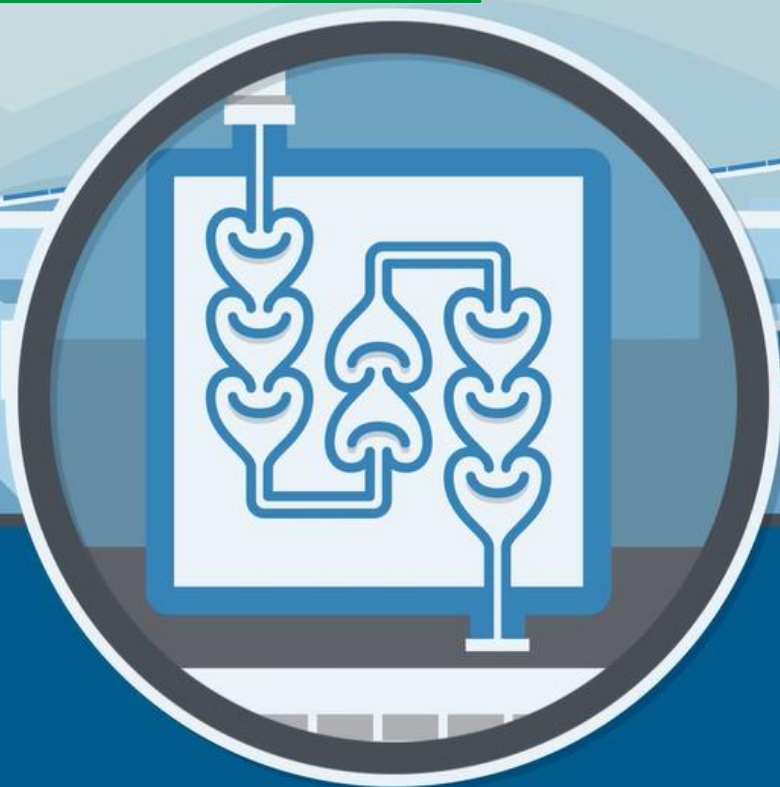


V= 0,54 ml

Scale up

		Light Intensity (Einstein/L*s)	
1 FM 420nm	3.69*10 <sup>-3</sup>	Gen1	
1 FM 405nm	3.14*10 <sup>-3</sup>		
1 FM 365nm	1.98*10 <sup>-3</sup>		
1FM 405nm	4.05*10 <sup>-3</sup>	Gen2	
1 FM 365nm	2.49*10 <sup>-3</sup>		
1 FM G3 420nm	4.78*10 <sup>-3</sup>		
Micoreactor 365nm*	0,71*10 <sup>-3</sup>		

\*Prat et al, International J. Chem. React. Eng. 2014; 12(1): 257-289



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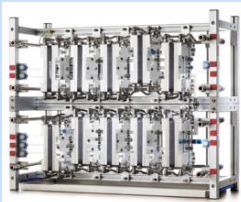
**Your next step in flow chemistry**

# From Lab to Industrial Production

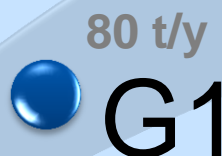
Application Process  
Development & Small  
Production

Industrial Production

Lab scale stepping  
into flow chemistry,  
Application process  
development



G1 SiC



80 t/y

G1



G1 Photo



G1 Glass

250 t/y



G2



G2 SiC

1000 t/y



G3



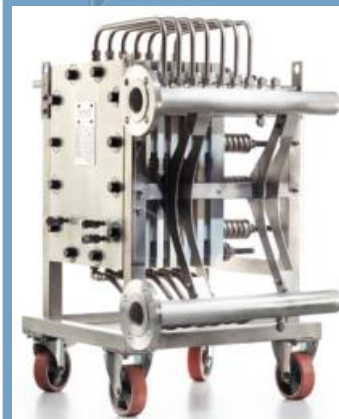
G3 Glass

2000 t/y

G4

3500 t/y

GP4



SiC

## Concluding Remarks

- **Corning Advanced-Flow Reactors provide**
  - High Mass transfer
  - High Volumetric Heat transfer
  - Seamless Scale-up
- **Corning Advanced-Flow Reactors deliver**
  - High performance reactors
  - Turn key solution with all auxiliaries needed
  - Customised solution to fit individual needs
- **Corning Advanced-Flow Reactors support**
  - Customers all over the world
  - With a strong R&D team
  - To allow you to go fast to production





Thank for your attention

