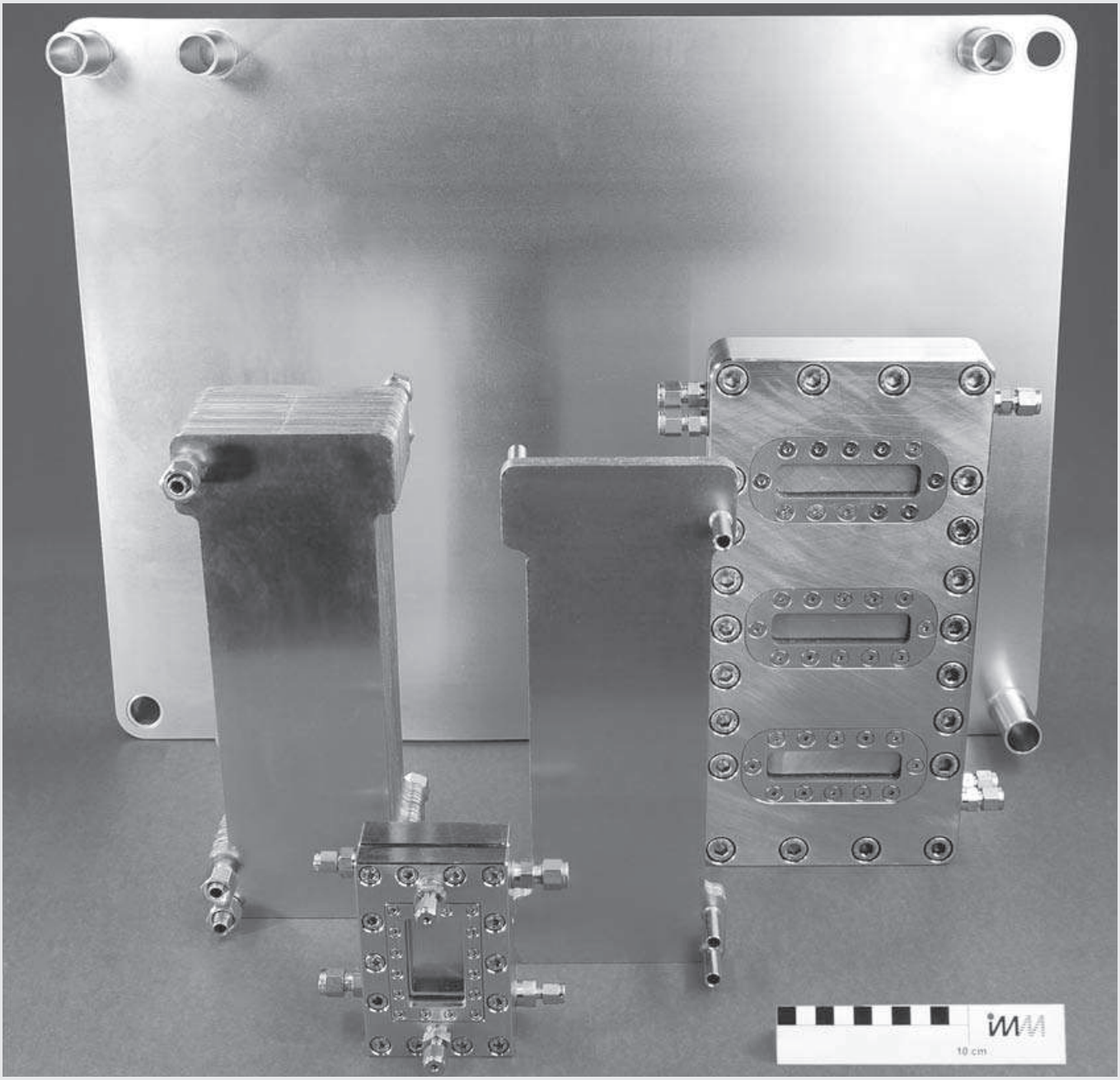
FALLING FILM MICROREACTOR

FFMR GROUP

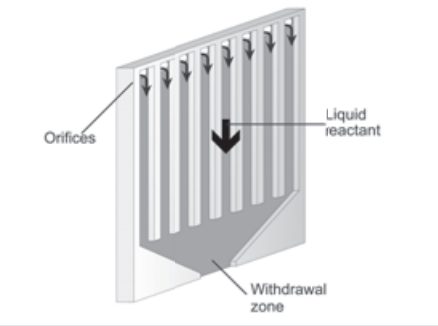


Members of the extended Falling Film Microreactor family

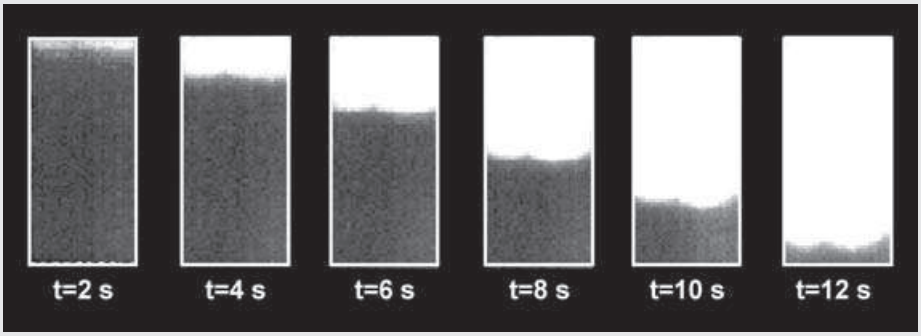
Principle

The Falling Film Microreactor utilizes a multitude of thin falling films that move by gravity force for a typical residence time of seconds up to about one minute. Its unique properties are the good temperature control by an integrated heat exchanger and the specific interface of 20,000 m^2/m^3. Such high mass and heat transfer were e.g. exploited when performing direct fluorination of toluene with elemental fluorine in the original version of IMM´s Falling Film Microreactor (FFMR-STANDARD). This so far uncontrollable and highly explosive reaction could be managed under safe conditions and with control over the reaction mechanism and therewith selectivity.

Due to the high raised interest for such a kind of device, starting from the FFMR-STANDARD in recent years the concept has faced several extensions and even more important has been brought from lab scale to pilot and production scale. The several types of Falling Film Microreactors including the new ones are introduced in the following.

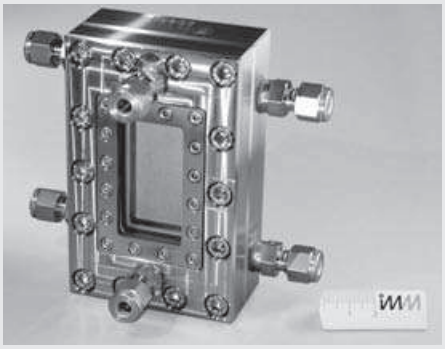


Falling film principle in a multi-channel architecture

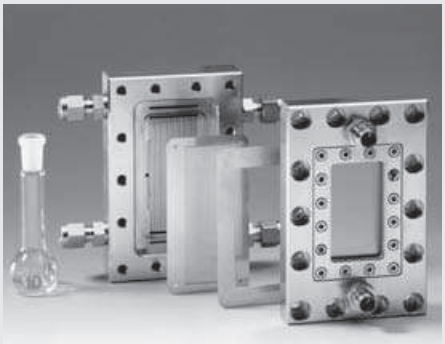


Thermographic monitoring: Initial wetting flow (FFMR-STANDARD)

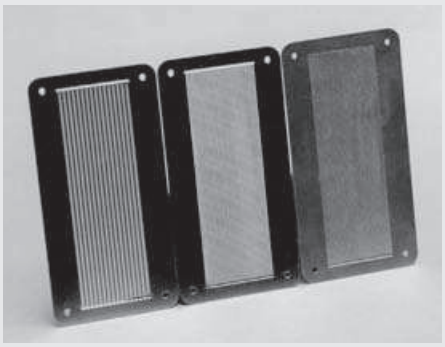
FFMR Standard



Reactor assembled



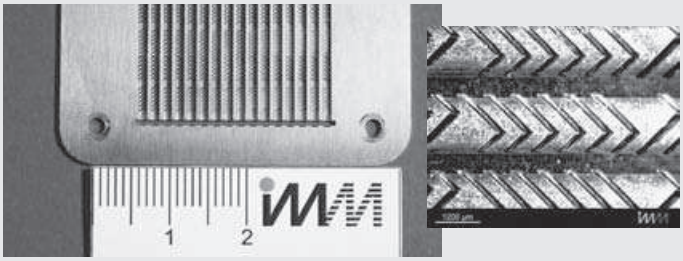
Reactor disassembled



Reaction plates

Research Topics at IMM

IMM is exploring the potential of further structuring the straight reaction channels in the Falling Film Microreactor. So IMM realised recently a reaction plate in which each of the channels have been modified by incorporation of additional grooves in order to improve via recirculation flows the liquid side mass transport. First tests based on CO_2 absorption in aqueous sodium hydroxide have proven that significant performance improvements can be achieved.



Technical Data

Name	Falling Film Microreactor (Standard)
Order number	FFMR-STANDARD
Size (L x B x H)	120 x 76 x 40
Connectors (Inlet/Outlet)	all 1/4″
Material	1.4571 for housing and reaction plate Copper for cooling plate Borofloat glass for inspection
Standard reaction channels (µm)	300 x 100 (64 channels) 600 x 200 (32 channels) 1200 x 400 (16 channels)
Reaction channel length (cm)	7.6
Gas chamber height (mm)	5
volume of gas chamber (mm^3)	13336
Standard cooling channels (mm)	Width: 1.5 Depth: 0.5
Options	Other materials like Hastelloy, Monell or Titan on request

Operating Conditions

Temperature (°C)	180 (option: 300)
Pressure stability (bar)	10 (without Borofloat glass: 20)
Flowrate (l/h)	0.05 for channel geometry 300 µm 0.6 for channel geometry 600 µm 1.5 for channel geometry 1200 µm
Residence time (s)	0.8 – 20
Liquid film thickness (µm)	25 – 100
Interfacial area (m^2/m^3)	up to 20000
Leakage Class	$L_{0.01}$

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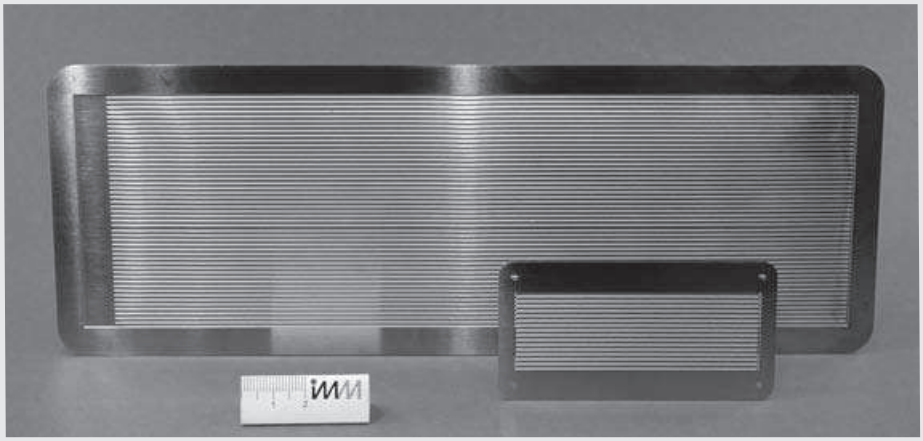
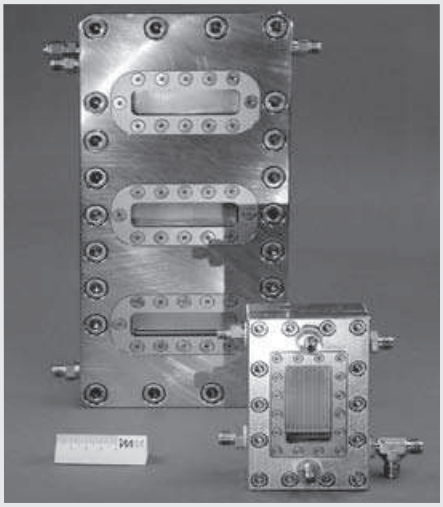
FFMR-LARGE & FFMR-CYLINDRICAL



Reaction plates for FFMR-STANDARD and -LARGE



FFMR-STANDARD and -LARGE

Starting from FFMR-STANDARD two new reactor types have been developed targeting at a tenfold increase of the structured surface area on the reaction plate. In the FFMR-LARGE therefore the length and the number of channels have been increased by a factor of $10^{0.5}$. From the general design FFMR-LARGE is quite similar to FFMR-STANDARD. FFMR-CYLINDRICAL follows another approach. The reaction channels are now engraved on the outside of a metallic tube. The cylindrical shape allows a quite compact design in this case. The number of the reaction channels has been increased by a factor of 7.5, the length of the channels has been elongated a bit to get a tenfold increase of structured surface area. The FFMR-CYLINDRICAL is of special interest for photochemistry applications.

FFMR-CYLINDRICAL

Technical Data

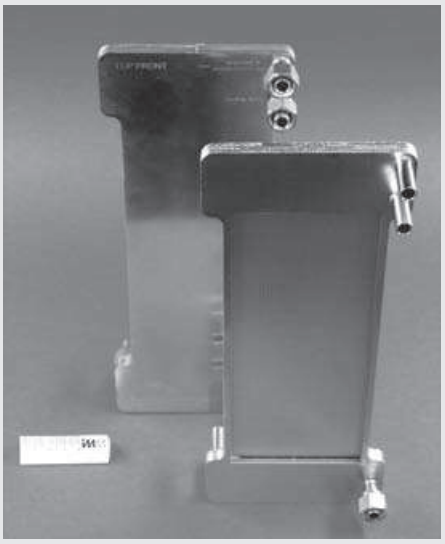
Name	Falling Film Microreactor Large	Falling Film Microreactor Cylindrical
Order number	FFMR-LARGE	FFMR-CYLINDRICAL
Size (L x B x H)	320 x 156 x 40	80 x 130
Connectors	all 1/4´´	1/8´´ and 1/4´´ (welded tubes)
Material	1.4571 for housing and reaction/cooling plate Quartz glass for inspection	1.4571 DURAN® glass for inspection
Standard reaction channels (µm)	1200 x 400 (50 channels)	1200 x 400 (120 channels)
Reaction channel length (cm)	about 25	about 10
Gas chamber height (mm)	4,5	5
Volume of gas chamber (mm^3)	90000	100000
Standard cooling channels (mm)	Width: 0.2 Depth: 0.4	Width: 1.2 Depth: 1.0
Options	Other materials on request	Other materials on request

Operating Conditions

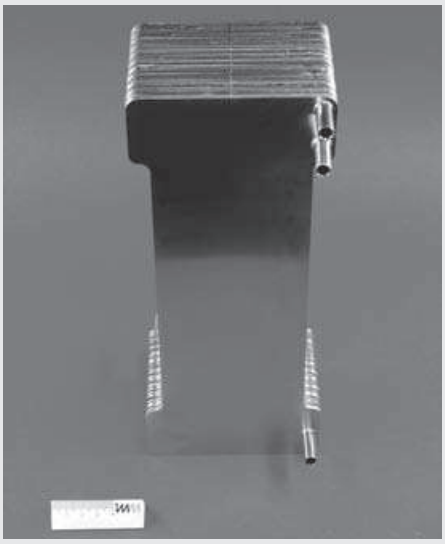
Temperature (°C)	180	180
Pressure stability (bar)	10 (without glass: 20)	5
Flowrate (l/h)	investigated range 0.24 - 1.20	investigated range 0.24 - 1.20
Residence time (s)	calculated 23 - 8	calculated 16 - 6
Liquid film thickness (µm)	calculated 60 - 100	calculated 45 - 76
Interfacial area (m^2/m^3)	about 9814 - 16780	about 13140 - 22470

Brazed Falling Film Microreactors (STACK-FFMR)

STACK-1x-FFMR-LAB



STACK-1x-FFMR-LARGE (open/closed)



STACK-10x-FFMR-LARGE

The reactor concept of FFMR-STANDARD and -LARGE has been transferred to a pure plate design to which brazing as joining technology can be applied. The STACK-1x-FFMR-LARGE thereby represents the equivalent to FFMR-LARGE and the basic functional element for following numbering-up. So STACK-10x-FFMR-LARGE contains 10 functional elements. To round up the brazed reactor program also a new lab version has been developed (STACK-1x-FFMR-LAB). Compared to STACK-10x-FFMR-LARGE it should allow identical experimentation at a throughput of only 1/100 of the STACK-10x-FFMR-LARGE. Brazing technology opens the door for specifically adopted reactors for high pressure applications.

Outlook for even larger reactors: test reaction plate for FFMR-XXL

Technical Data

Name / Order number	STACK-1x-FFMR-LAB	STACK-1x-FFMR-LARGE	STACK-10x-FFMR-LARGE
Size (L x B x H)	294 x 28 x 19	296 x 118 x 12	296 x 118 x 75
Connectors	all 1/8´´	all 3/8´´	all 3/8´´
Material	1.4571 + Ni screen printing braze	1.4571 + Ni screen printing braze	1.4571 + Ni screen printing braze
Standard reaction channels (µm)	1200 x 400 (50 channels)	1200 x 400 (50 channels)	1200 x 400 (50 channels)
Reaction channel length (cm)	about 25	about 25	about 25
Reaction channels number	5	50	500
Gas chamber height (mm)	4	4	4
Volume of gas chamber (mm^3)	7300	73000	730000
Standard cooling channels (mm)	Width: 1.2 Depth: 0.4	Width: 1.2 Depth: 0.4	Width: 1.2 Depth: 0.4
Options	On request	On request	On request

Operating Conditions

Temperature (°C)	180	up to 800 @ 1 bar	up to 800 @ 1 bar
Pressure stability (bar)	10	up to 50 @ 25 °C	up to 50 @ 25 °C
Flowrate (l/h)	about 0.02 - 0.12	about 0.24 - 1.20	about 2.4 - 12.0
Residence time (s)	about 23 - 8	about 23 - 8	about 23 - 8
Liquid film thickness (µm)	about 60 - 100	about 60 - 100	about 60 - 100
Interfacial area (m^2/m^3)	about 9814 - 16780	about 9814 - 16780	about 9814 - 16780