Lehrstuhl für Fluidverfahrenstechnik, Ruhr-Universität Bochum/D

Two phase flow in micro separation

technology (Extraktion, Absorption, Distillation)

Stabilization of the

interfacial area

Surface conditioning of

Falling films in micro

Phase-Equilibrium

Gibbs' Phase rule

F = K - P + 2

channel walls

Jähnisch et. al., Journal of Fluorine Chemistry 105 (2000) 117-128

Connecting

co-current modules

separation of dispersions

Generation and

or segmented flow

Pressure drop

in micro-

channels

ProcessNet JT 2008

Spatial separation of both

Chem. Eng. J. 101 (2004) 49-56.

Temperature &

concentration

gradient

Porous structures

Membranes

4

Process design for micro-structured distillation devices





• two fluid channels (interface stabilized by surface forces)

Micro-distillation devices presented in the last years:

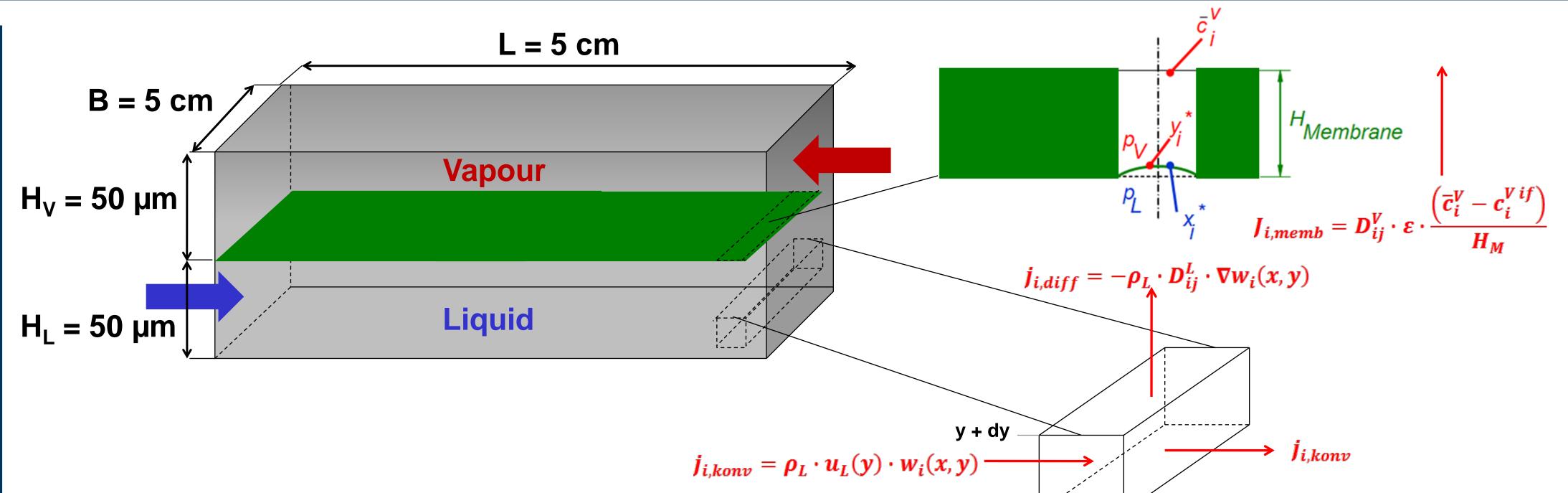
• two fluid channels (interface stabilized by capillary forces)

Advantages of micro-structured devices:

- high efficiency
- small hold-up
- modularity

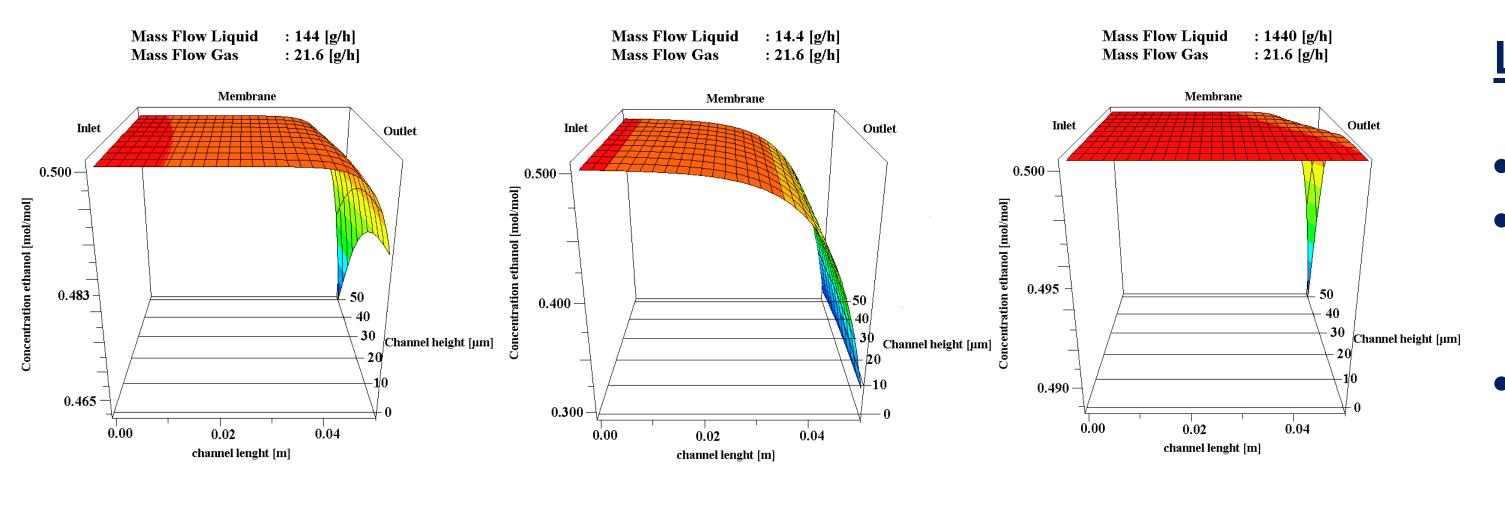
Questions not answered:

- operating limitations
- mass transport limitations



Rigorous process model:

- mixture of two substances
- steady state calculation
- laminar flow in both channels
- no-slip condition
- adiabatic conditions
 - → temperature gradient along membrane
 - → similar evaporation enthalpy
 - → constant total mole flow



Limitations for liquid flow:

- small temperature rise → no limitation
- upper bound
 - → residence time (diffusion vs. channel height)
 - → utilisation of membrane length
- lower bound
 - → economic efficiency (throughput vs. capital cost)

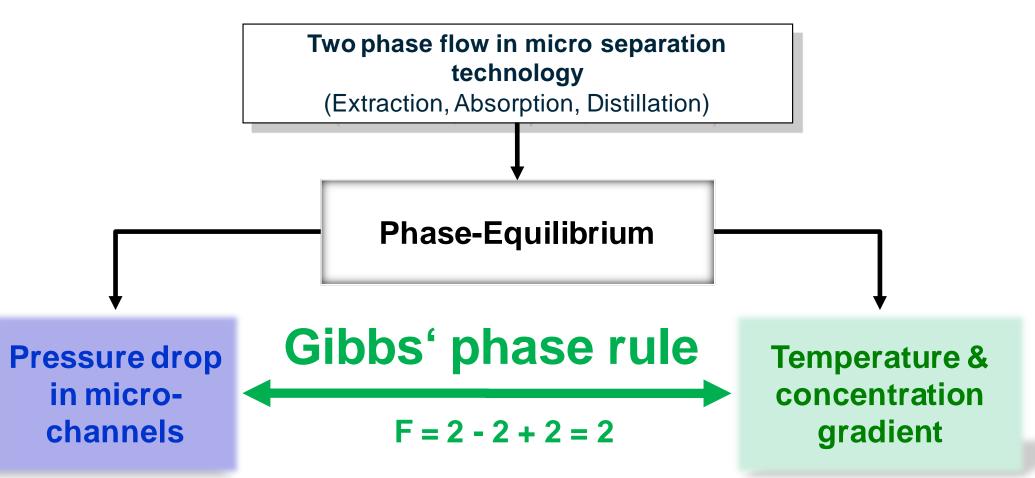
\dot{m}_{Lin} [g/h]	288	288	288	288
<i>m</i> _{V in} [g/h]	21,6	64,8	108	216
$\dot{m}_{\scriptscriptstyle membran~EtOH}$ [g/h]	4,19	12,19	19,50	31,69
ΔT [K]	1,26	3,73	6,56	16,82
∆p _{manibran max} [bar]	0,25	0,36	0,47	0,82

Limitations for vapour flow:

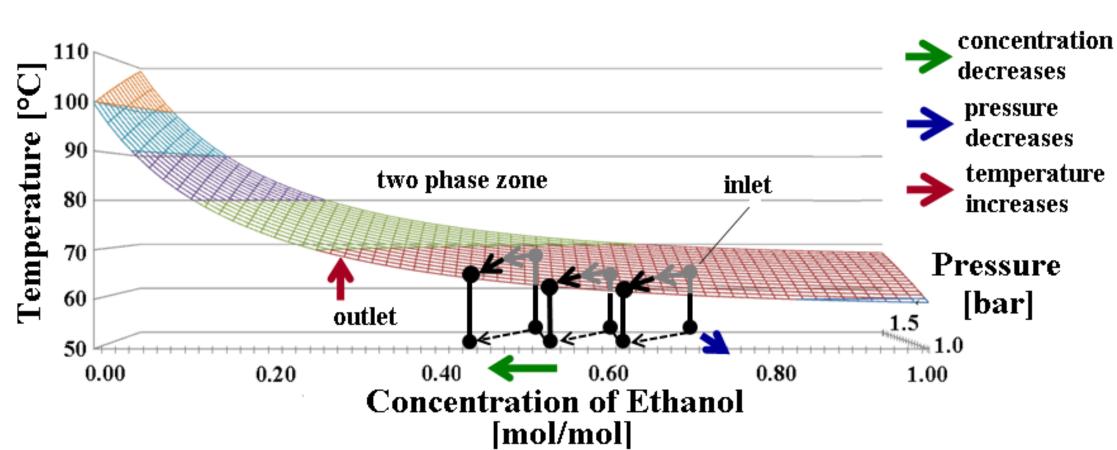
x + dx

Ji,diff

- upper bound
 - \rightarrow temperature rise (max. ΔT of device)
 - \rightarrow pressure drop (Δ p vs. capillary pressure of membrane)



concentration decreases <u>D</u> 100 pressure decreases temperature two phase zone inlet increases Pressure [bar] outlet 0.001.00 **Concentration of Ethanol** [mol/mol]



Consequences for process design:

- pressure drop limits mass transfer
- pressure drop depends on geometries
- pressure drop per module limited
- stepwise increase of pressure for defined distillation task

Phase-equilibrium at membrane:

- pressure drop fixed by channel geometrie
- concentration fixed by mass transfer
- temperature fixed by Gibbs' phase rule
- no degree of freedom