



# New ED - Advanced Bipolar Membrane Processes for Remediation of Highly Saline Wastewater Streams

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- New ED Project
- Introduction
- Objectives and concept of the project
  - Corrugated membrane approach
  - Results
  - Conclusions
- Status of the project



- 3-year EU project
- **Objective:** Development of new type of bipolar membranes to treat highly saline wastewater streams
- 5 work packages
  - WP 1 Membrane development
  - WP 2 Module development
  - WP 3 Testing and Evaluation
- 5 project partners

# Project partners

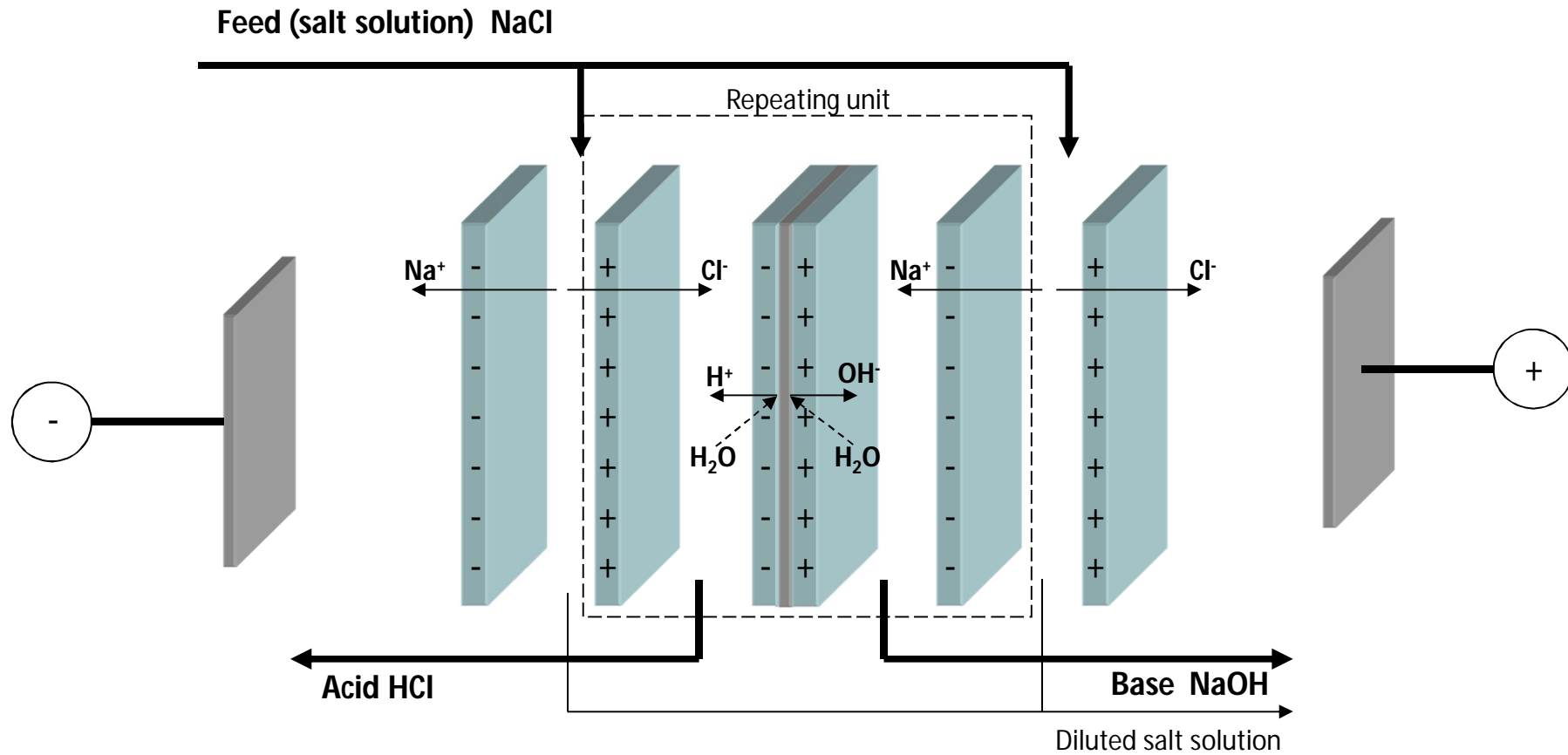
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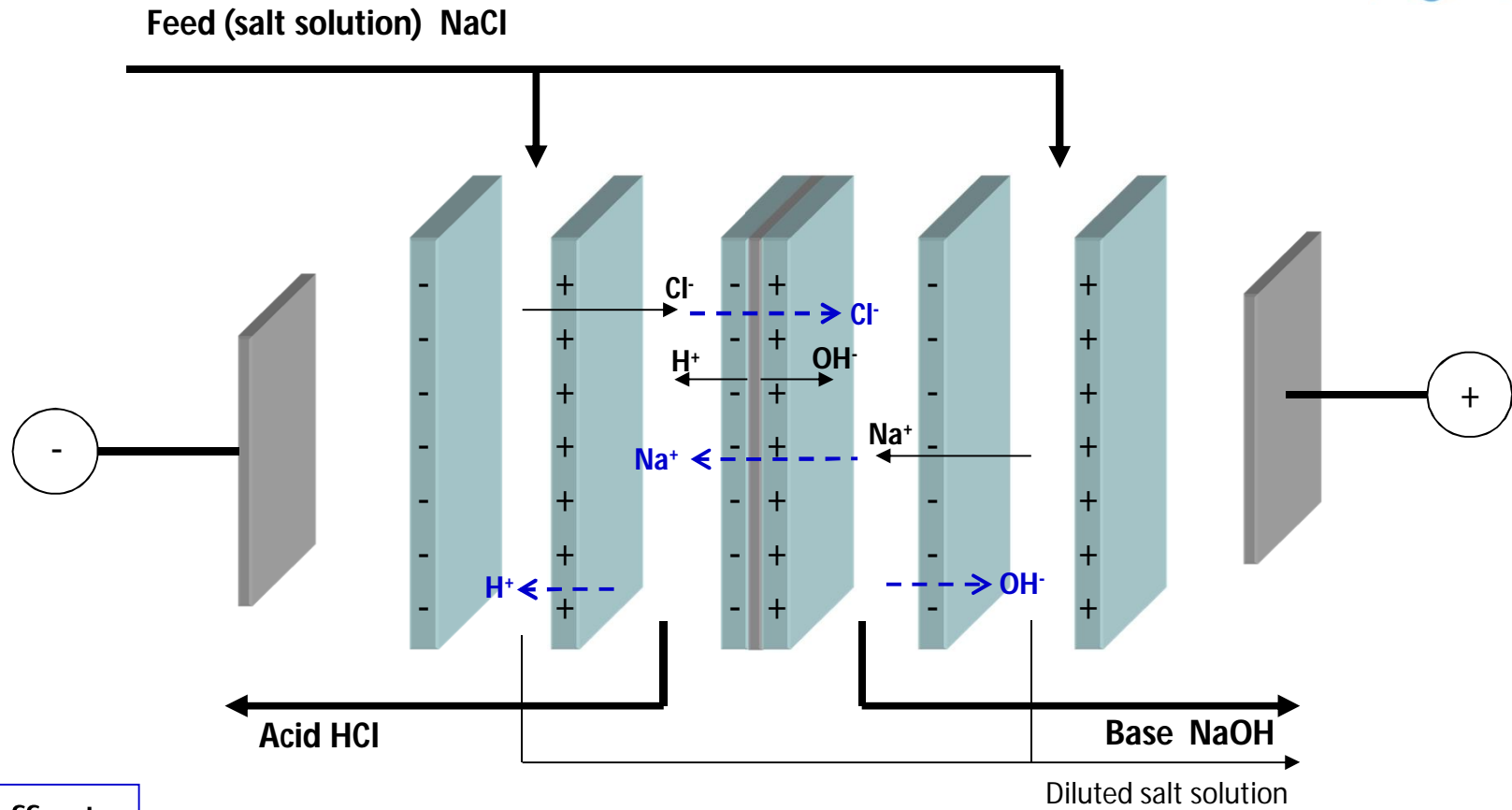
UNIVERSITY OF TWENTE.



# Principle of Electrodialysis using Bipolar Membranes (EDBM)



# Limitations of EDBM



## Undesired effects

Higher product concentration

- Bipolar**
  - Salt ion transport

- Monopolar**
  - Co-ion transport

High current density

- Efficiency loss
- Dehydration → membrane resistance ↑

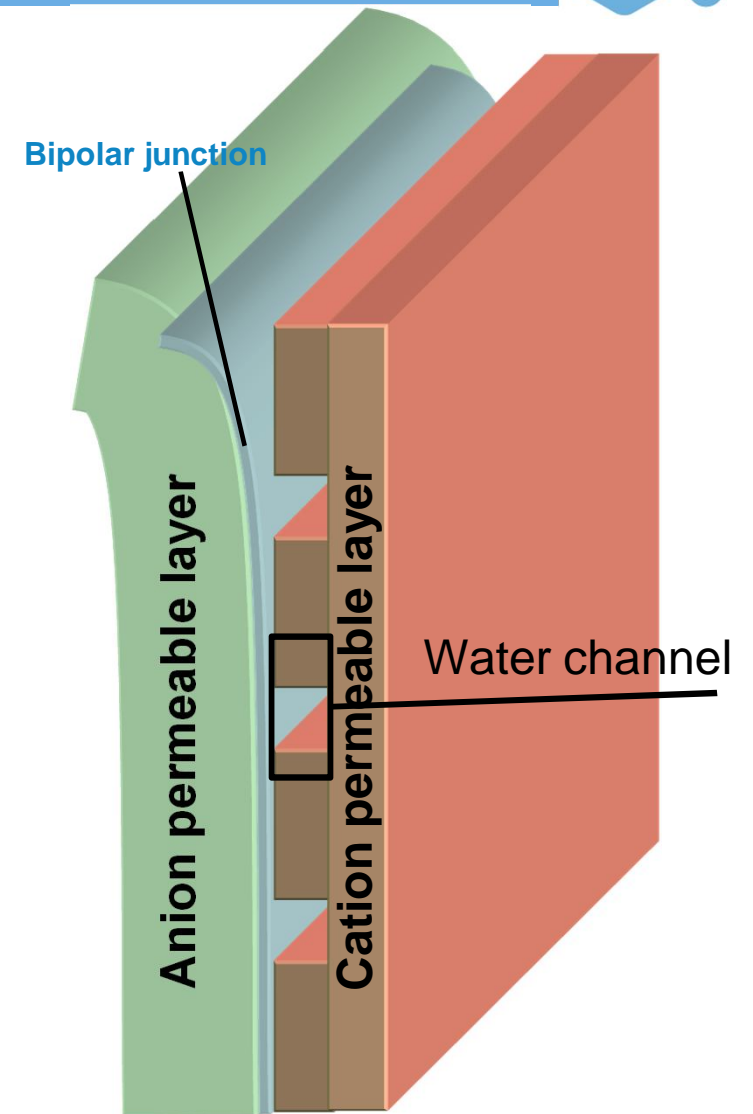
# Concept of the new membrane



- **Convective** instead of **diffusive** water transport to the bipolar membrane via:
  - Ion-conductive porous intermediate layer

## Water transport to the inside of the BPM

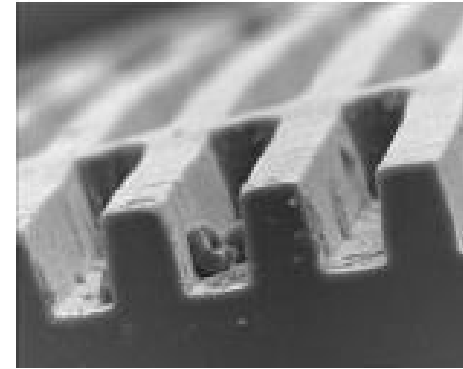
- New ED: transverse to the ion flux ,driven by external pressure
- Conventionally: in a direction opposite to the ion transport



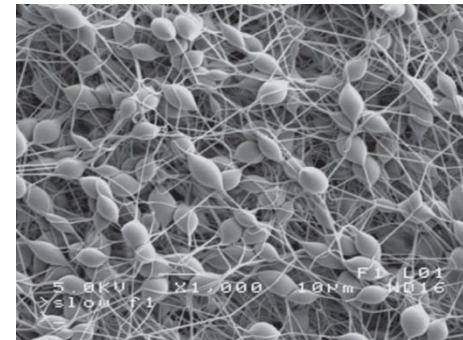
Decouple requirement of high selectivity and high water permeability



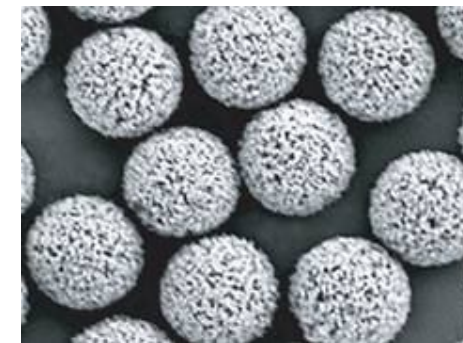
- Four manufacturing approaches:
  - Corrugated membrane
  - Sulfo-chlorination
    - micro-porous PE substrate
    - woven or non-woven PE fibers
  - Ion conductive fleeces
  - Porous ion exchange resin layer



Source: Balster et al.



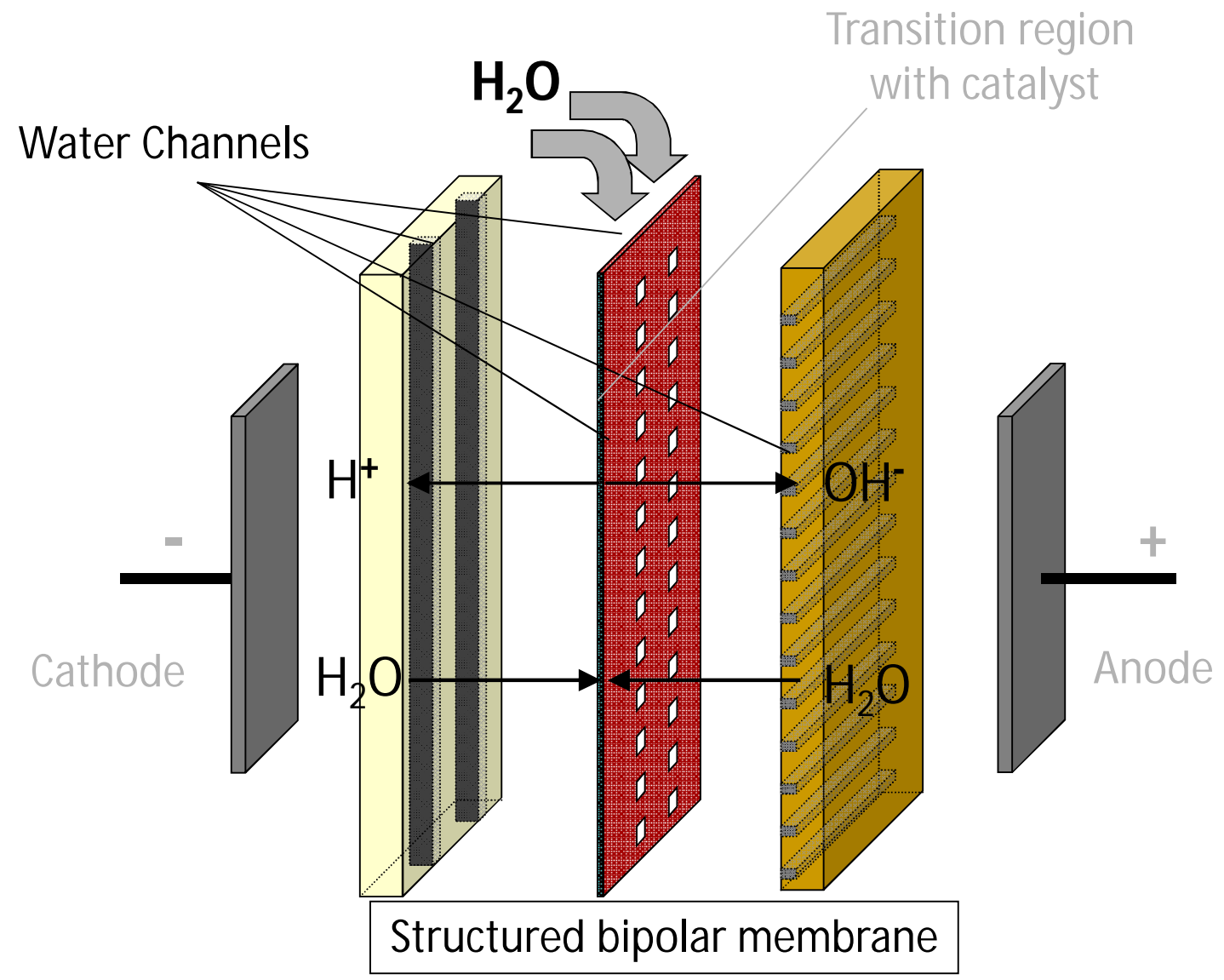
Source: NRC Canada



Source: Crawford Scientific



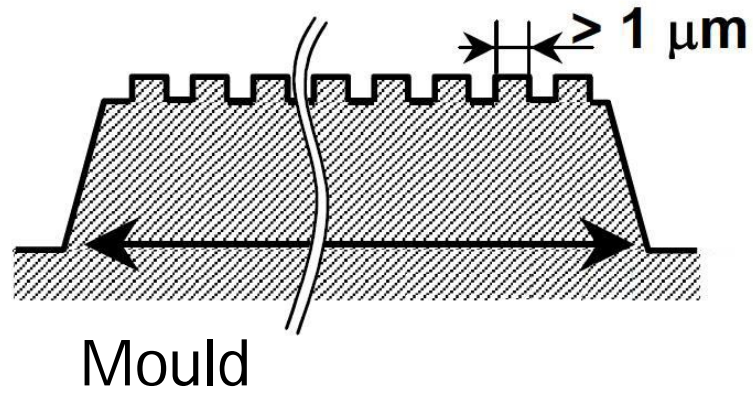
# Concept of the new membrane – corrugated membrane approach



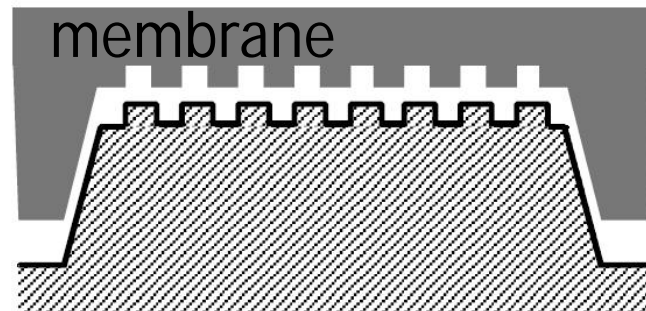
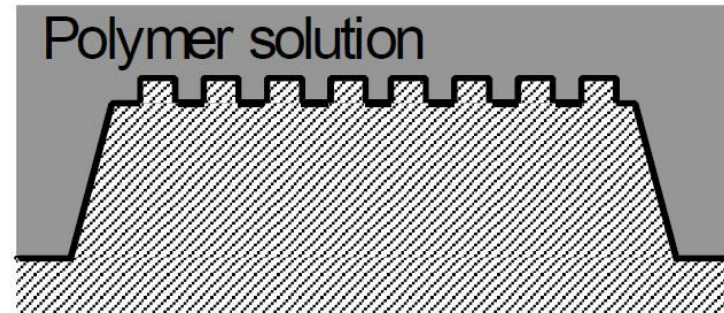


- Three crucial steps:
  - 1<sup>st</sup>** Controlled preparation of the **mould**
  - 2<sup>nd</sup>** **Casting** of the polymer solution, retaining the structured pattern
  - 3<sup>rd</sup>** **Lamination** of the anion and cation exchange layers without damaging the water supply channels
- **4<sup>th</sup>** Module construction - Assuring uniform **convective supply of water** to the interface

# Corrugated membrane approach

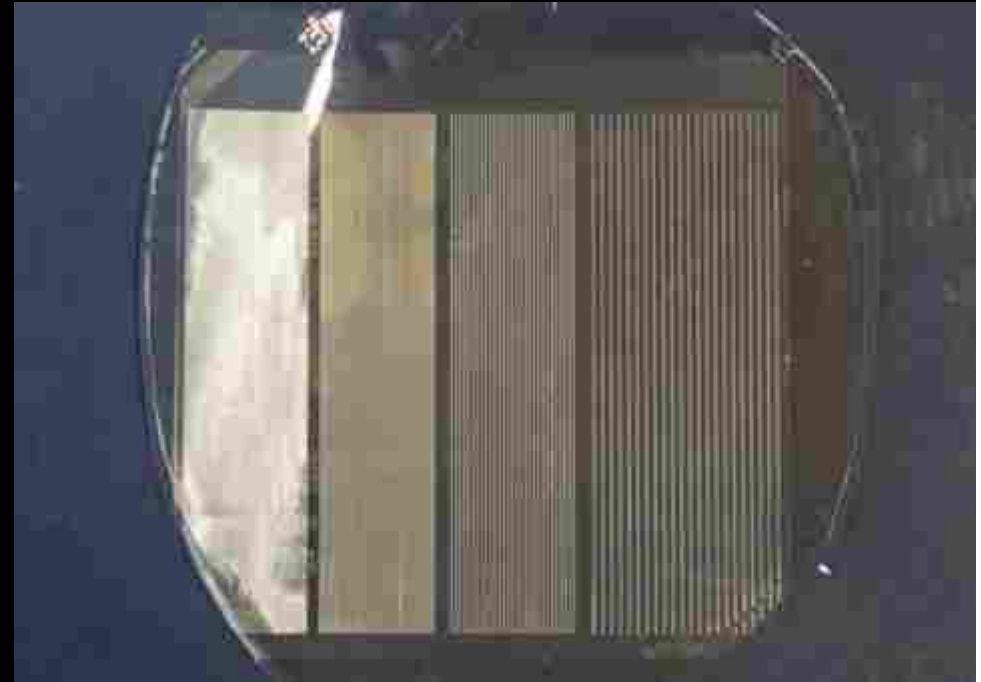


- Forming membrane with parallel patterns in a corrugated module



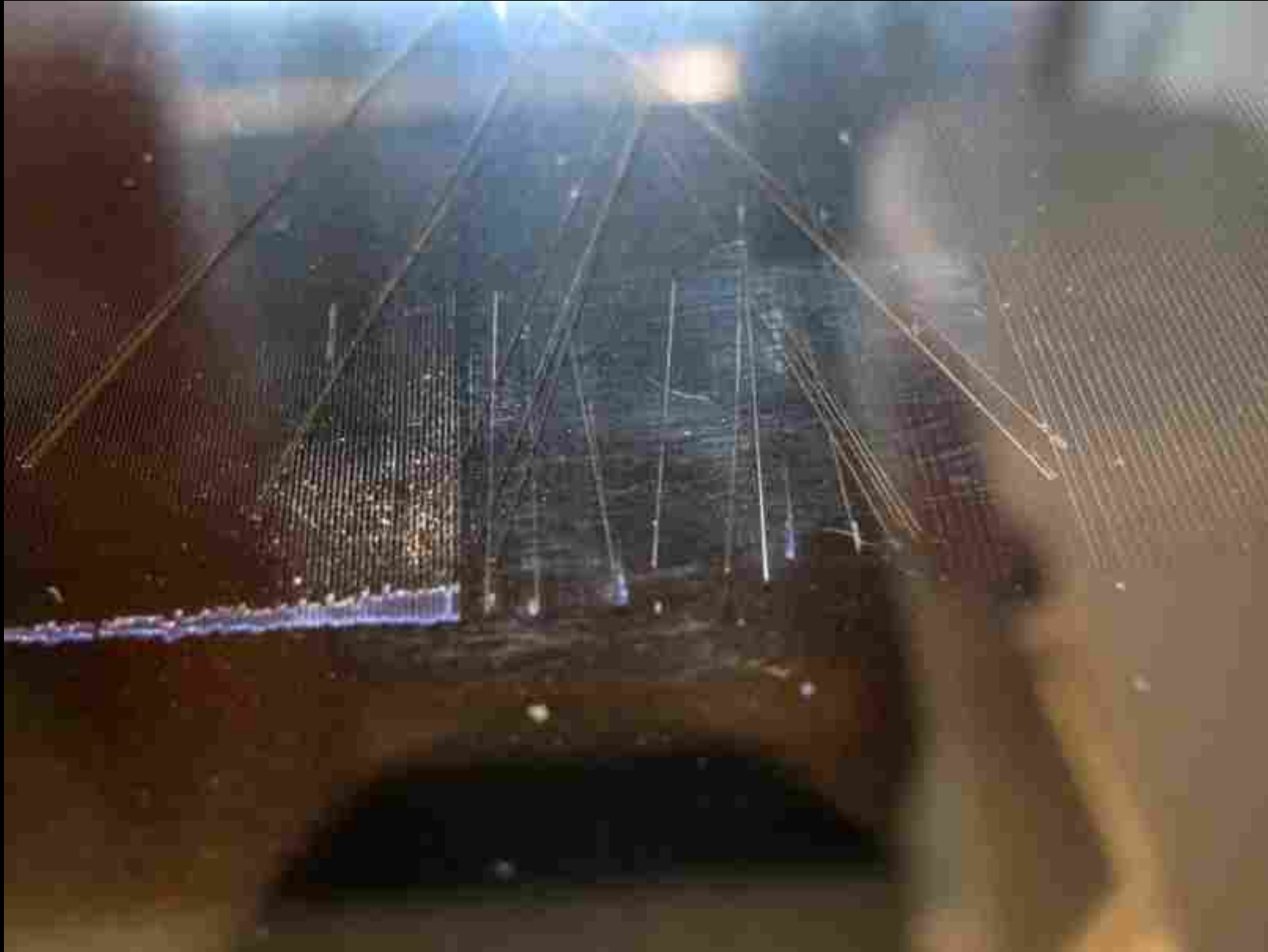
# Moulds from silicon wafer

1. Controlled preparation of the mould



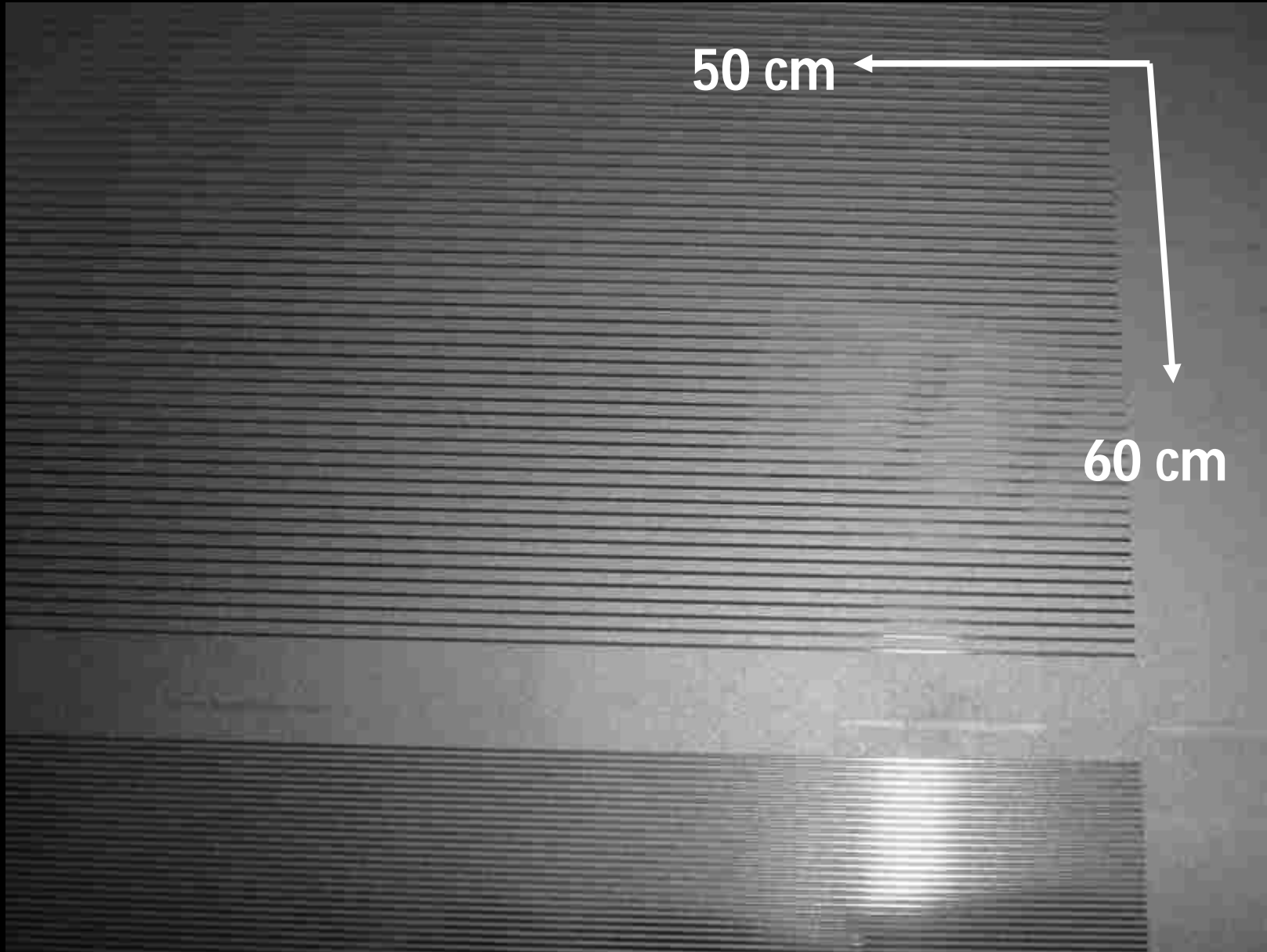
## Patterned SS moulds (Electroformation)

1. Controlled preparation of the mould



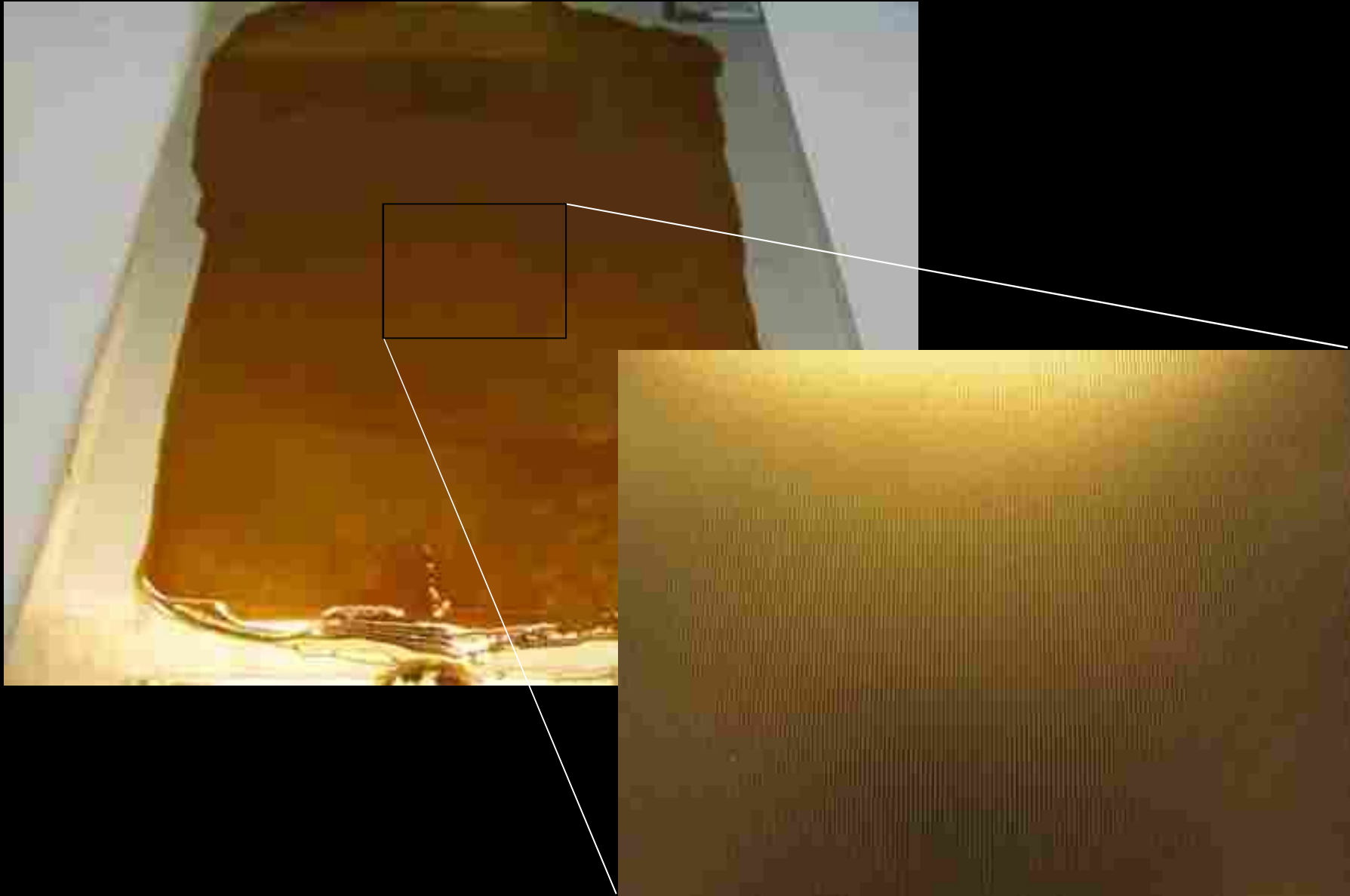
## Patterned SS moulds (Etching)

1. Controlled preparation of the mould



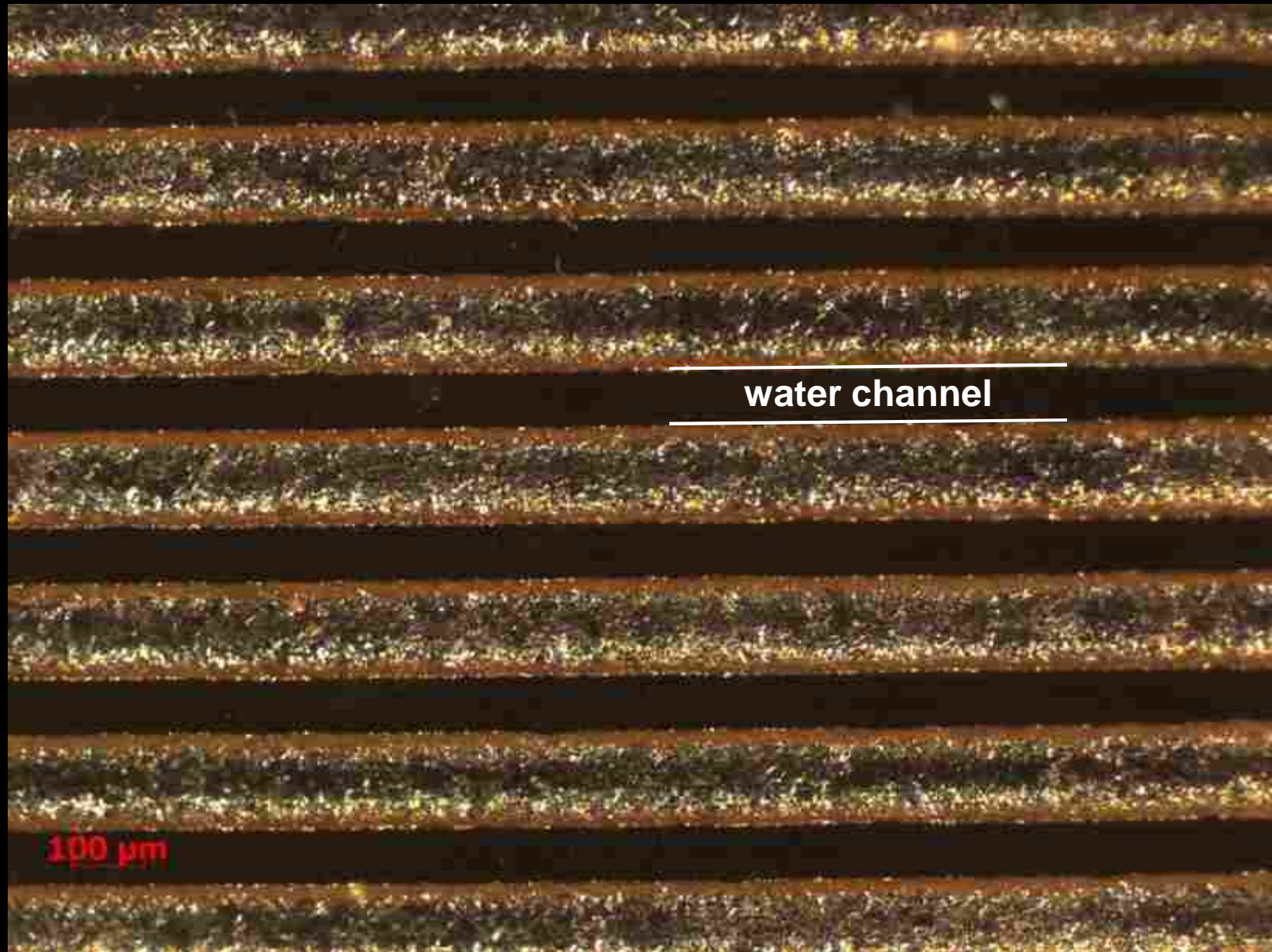
## Micro-structured flow channels (ED membrane)

2. Controlled casting of the polymer solution, retaining patterns





## Micro-structured flow channels (ED membrane)





## Water transport characterization



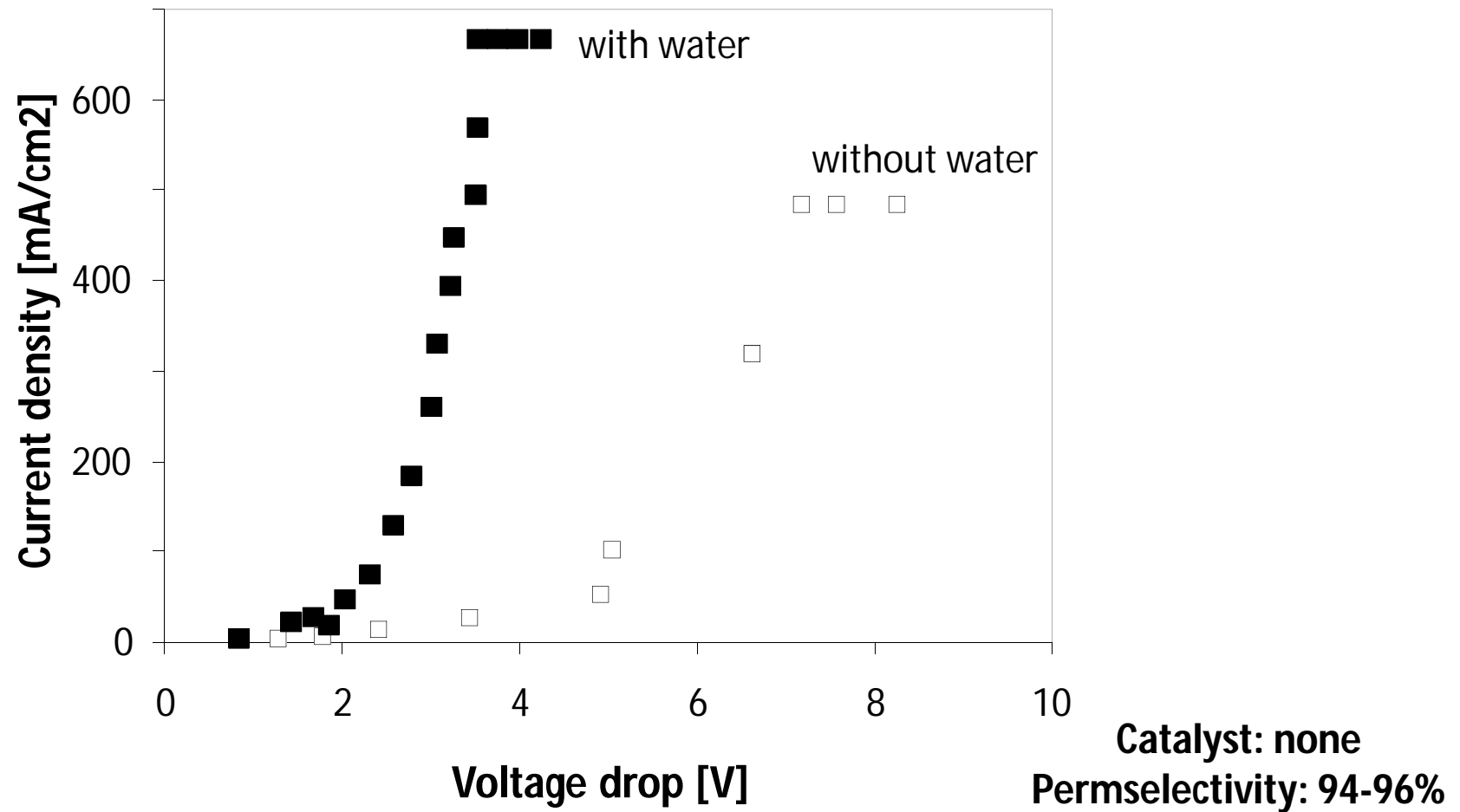
3. Controlled lamination of layers



# Bipolar Membrane Current Voltage Curve



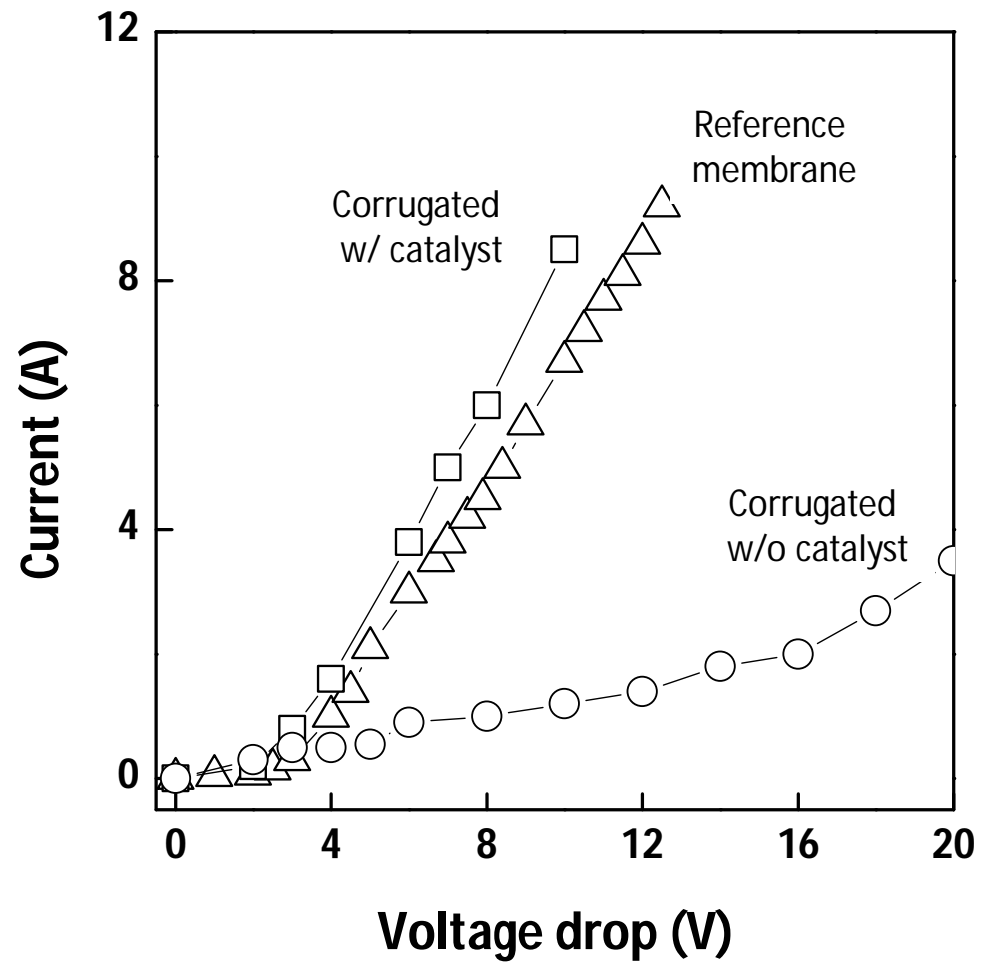
Small scale module



# Water transport characterization with catalyst



- Characterization in larger technical scale module with active water transport and catalyst

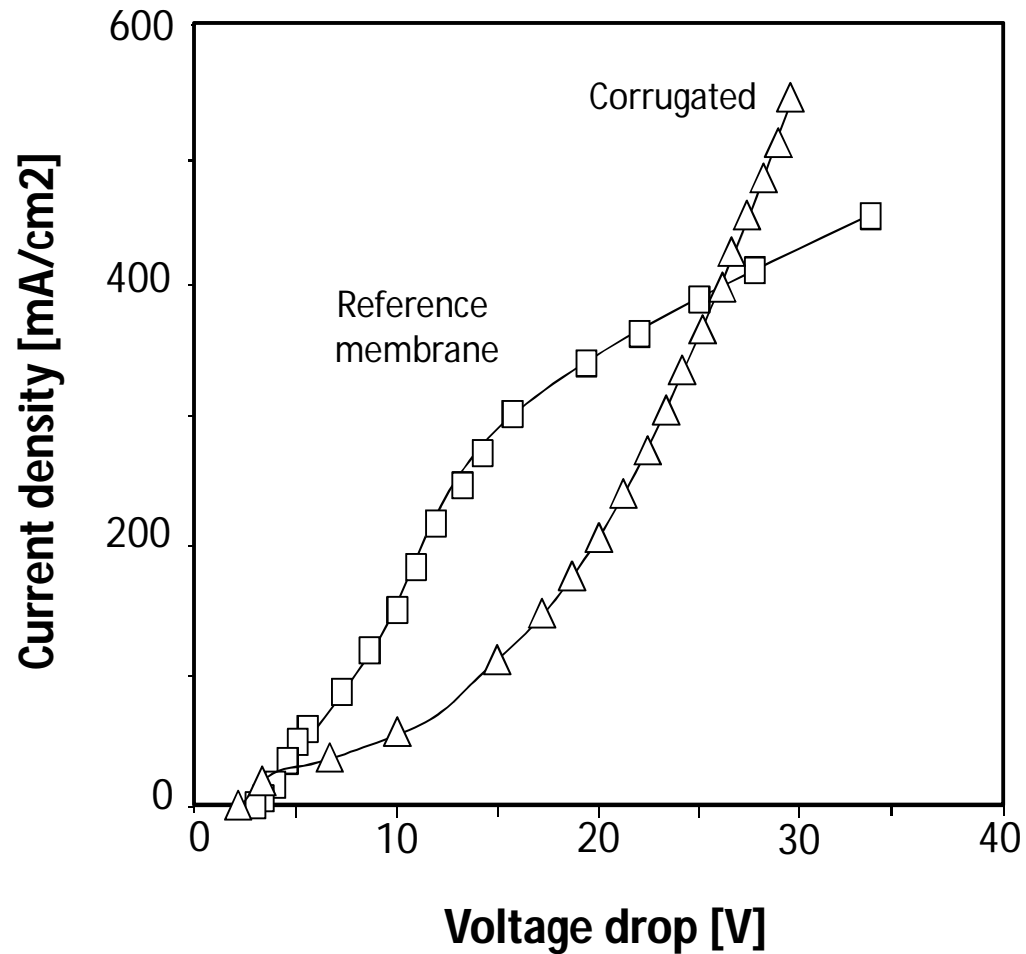


Lower current density

# Water transport characterization with catalyst



- Characterization in larger technical scale module with active water transport and catalyst



Higher current density



- Structured membranes can be produced without clean room technology
- Water channels increase *limiting current density*
- Membrane materials no longer have to be optimized for higher water diffusion



- Four-loop membrane module developed
  - Modified module design to minimize current leakage
  - Optimized spacer on basis of parasitic current, pressure drop and chemical resistance
- Ongoing
  - Development of lamination technique of two or more patterned layers
  - Optimization of channel dimensions



# Acknowledgment

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