Microscopic Investigation of Laminates for barriers of Vacuum Insulation Panels

presented by

Samuel Brunner

EMPA, Laboratory for Building Science and Technology
Ueberlandstr. 129, CH-8600 Dübendorf / Switzerland
samuel.brunner@empa.ch

with contributions of M. Stiefel, K. Ghazi Wakili

Structure of the two investigated laminates for the barrier envelopes of VIP's

Laminate L1 92 μm

J	PET	Polyethylene terephtalate	12 μm
I	AL	Aluminium	100 nm = 0.1 μm
H	PU	Polyurethane	2 μm
G	PET	Polyethylene terephtalate	12 μm
F	AL	Aluminium	100 nm = 0.1 μm
E	PU	Polyurethane	2 μm
D	PET	Polyethylene terephtalate	12 μm
C	AL	Aluminium	100 nm = 0.1 μm
B	PU	Polyurethane	2 μm
A	LDPE	Low Density Polyethylene	50 μm

Vacuum side

Laminate L2 108 μm

J	PET	Polyethylene terephtalate	12 μm
I	AL	Aluminium	60 nm = 0.06 μm
H	PU	Polyurethane	2 μm
G	AL	Aluminium	60 nm = 0.06 μm
F	PP	Polypropylene	18 μm
E	PU	Polyurethane	2 μm
D	AL	Aluminium	60 nm = 0.06 μm
C	PET	Polyethylene terephtalate	12 μm
B	PU	Polyurethane	2 μm
A	LDPE	Low Density Polyethylene	60 μm

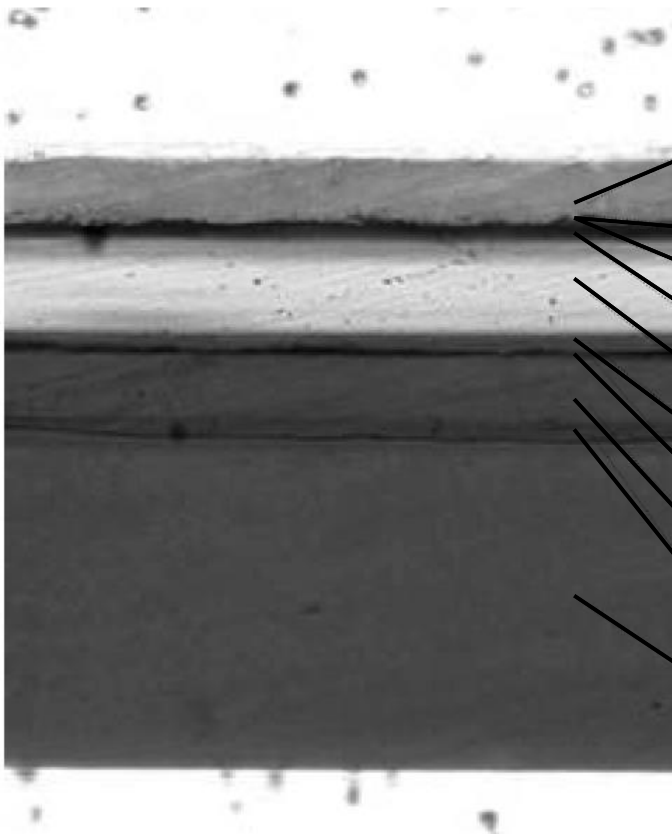
Vacuum side

(Not scaled)

EMPA

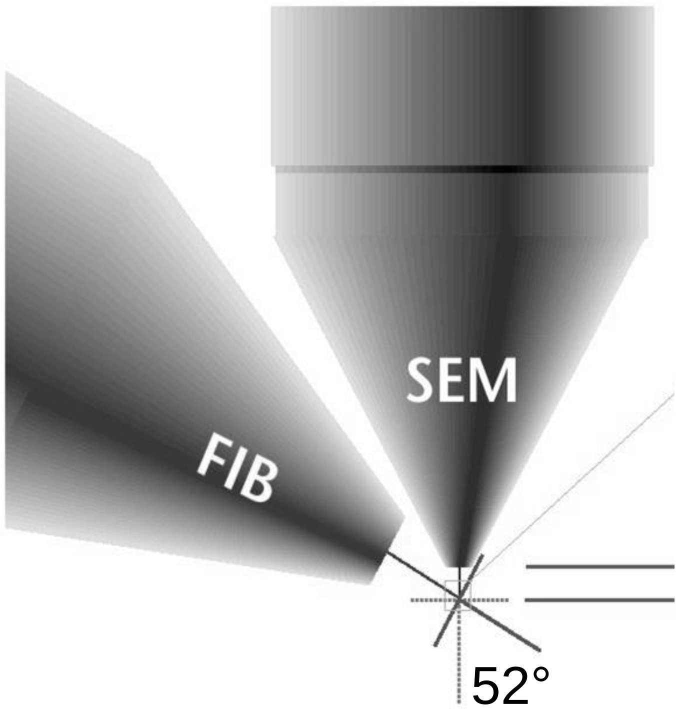
Laminate seen by optical microscopy (scaled)

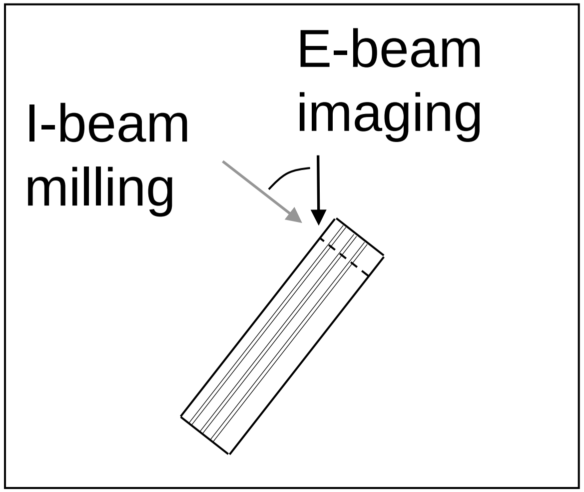
Laminate L2 - low visibility of aluminium layers

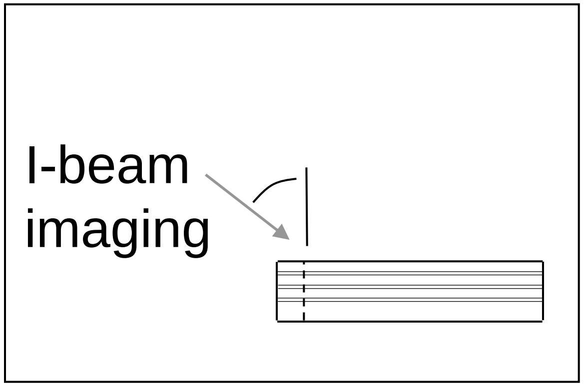


Layer #	Material	Function	Thickness
1	PET	Protecting layer (substrate for 2)	12 µm
2	ALU	Barrier layer	30 nm
3	PUR	Glue	2 µm
4	ALU	Barrier layer	30 nm
5	PP	Substrate for 4	18 µm
6	PUR	Glue	2 µm
7	ALU	Barrier layer	30 nm
8	PET	Substrate for 7	12 µm
9	PUR	Glue	2 µm
10	PE-LD	Sealing layer	60 µm

Schematic representation of the Focused Ion Beam method (FIB)



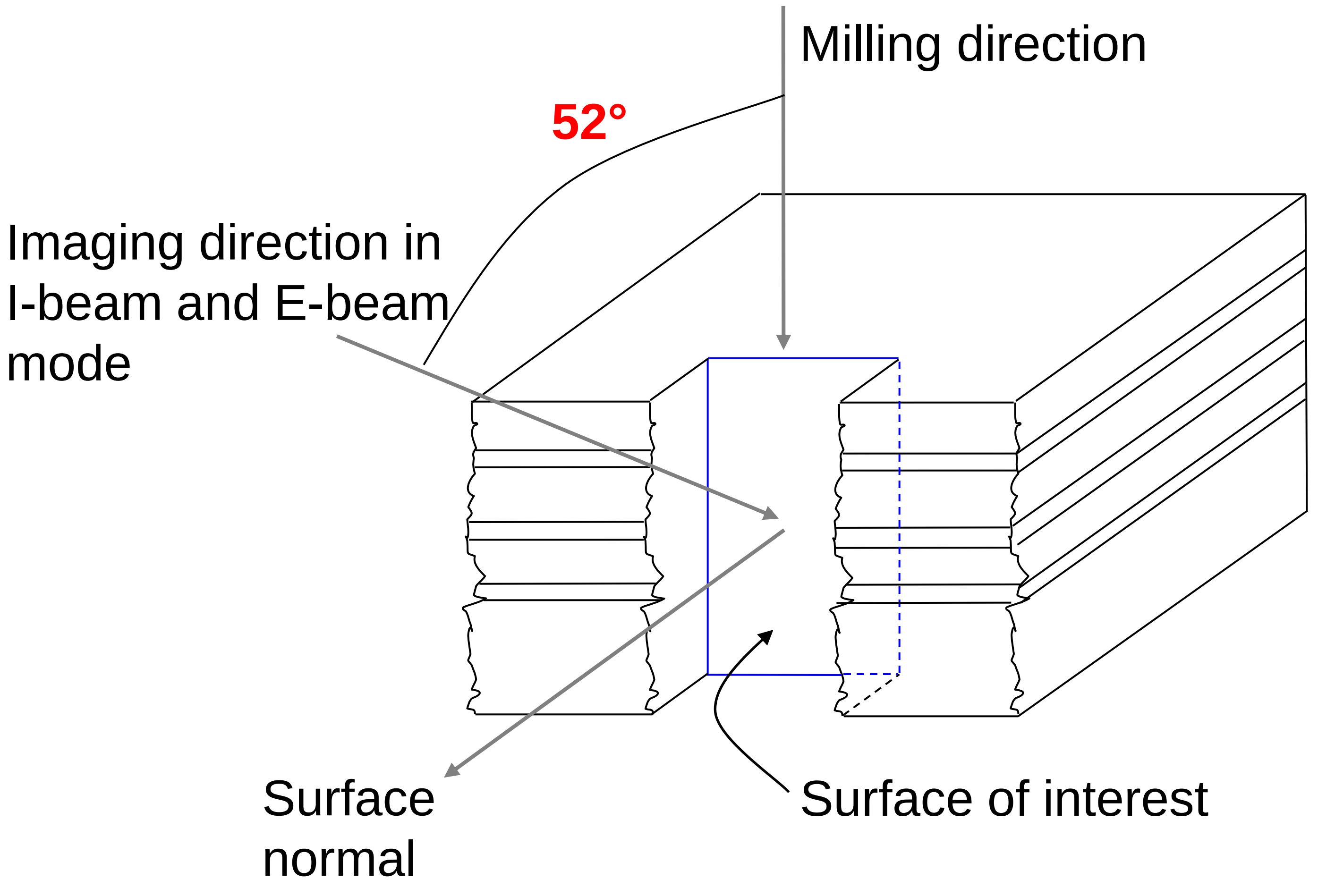




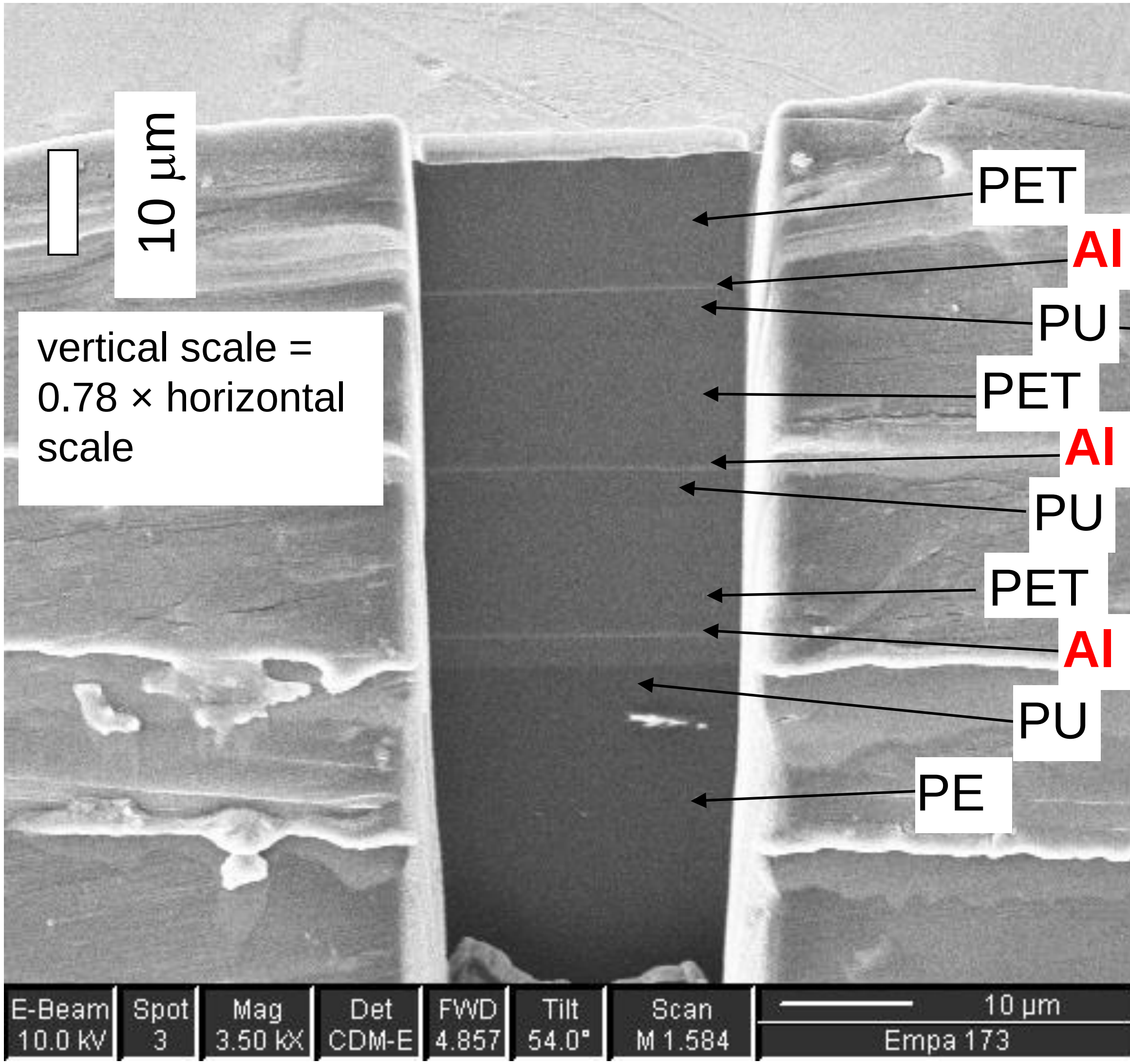
Dual Beam - 2 switchable sample positions

EMPA

prepared area is seen under an angle of 52°



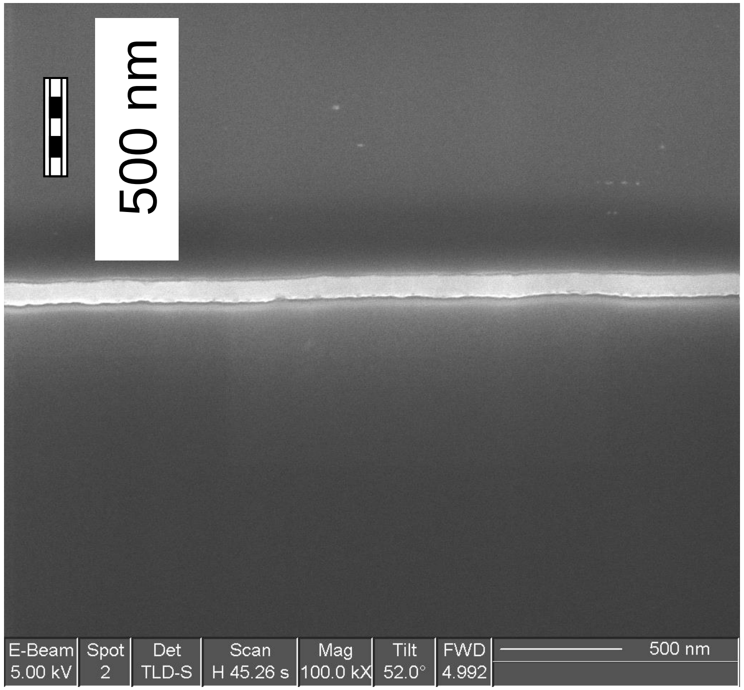
Overview of the different layers

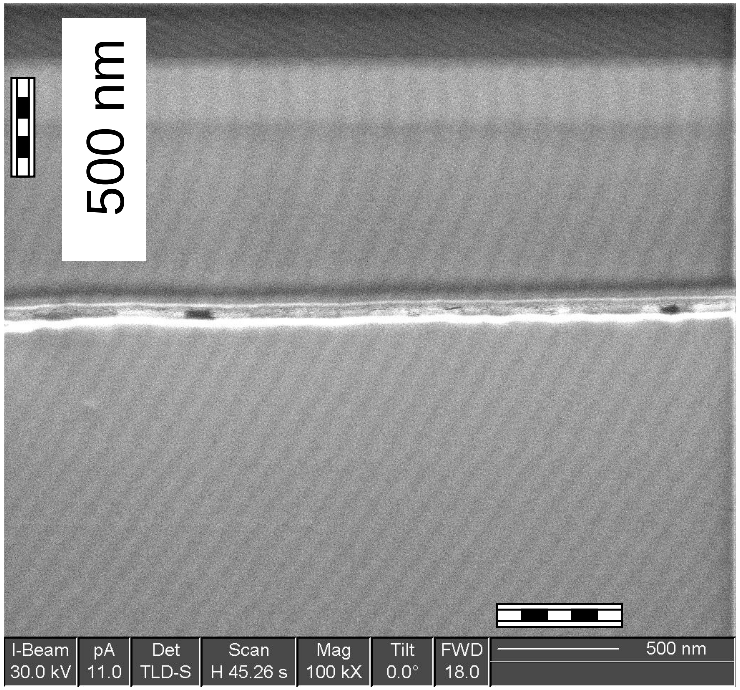


- PET a relatively hard plastic with superior flat surface, an excellent substrate for the
- metallic barrier layer (Al).
- polyurethane (PU) is the glue between films
- Polyethylene (PE) is the sealable layer, lowest melting temperature

EMPA

Barrier layer - unaged

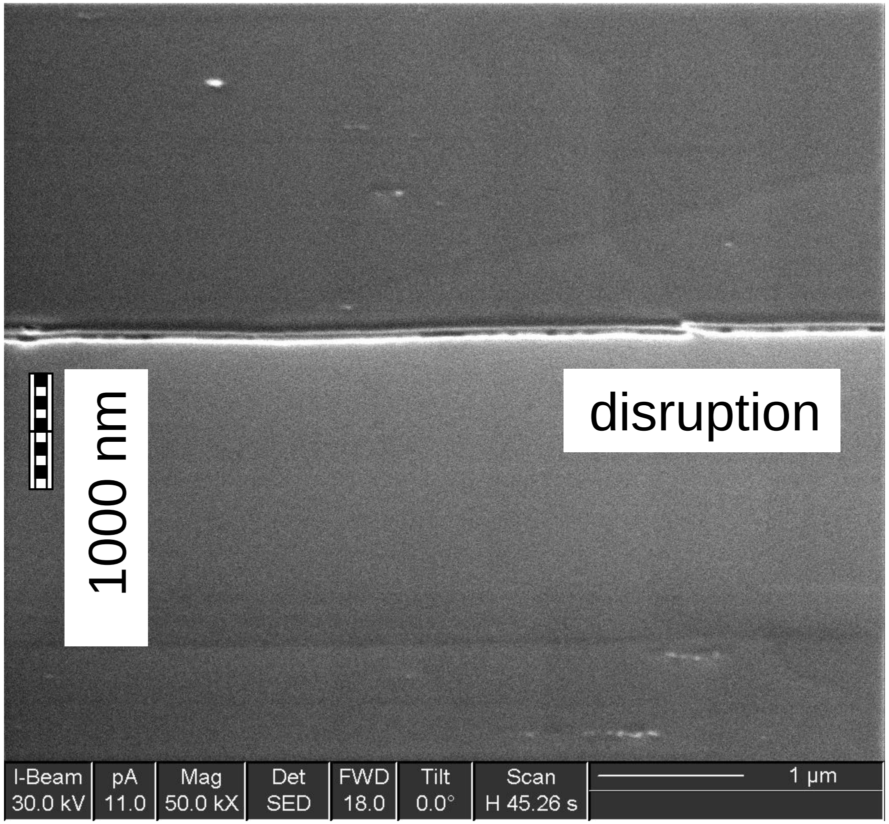


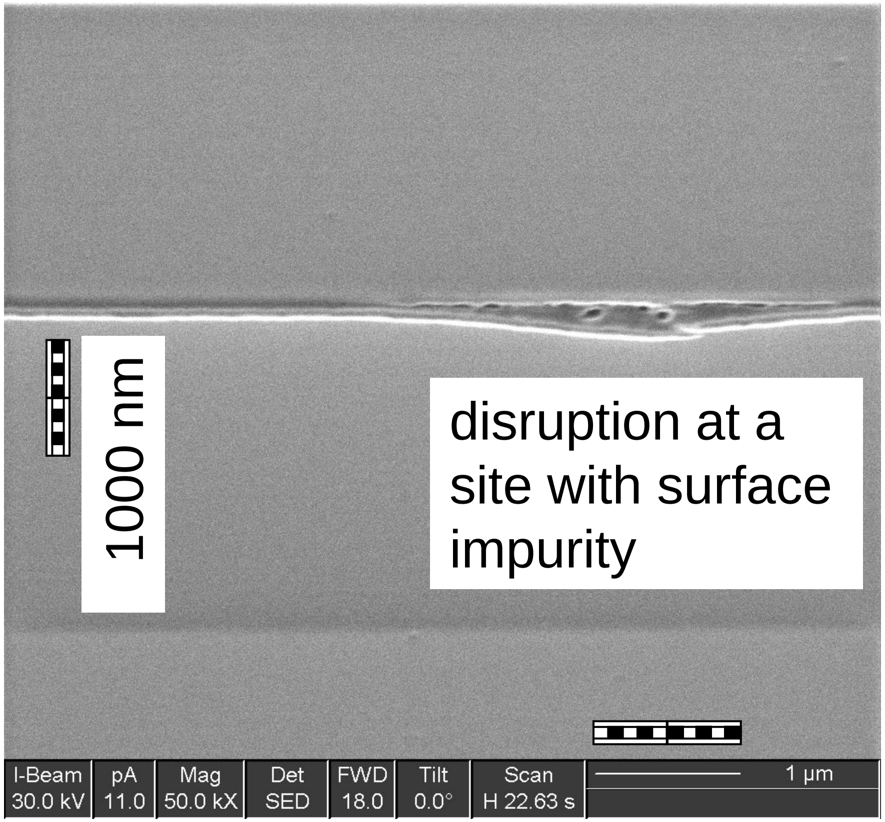


- Depending on the nature of the Beam (Ion / Electron) different contrast are produces at the barrier layer (aluminium)
- The different orientation of the metallic crystallites can lead to strong contrast in the Ion-beam image (left)

EMPA

Fresh, unaged laminates





- Smallest defects are visible, which are hardly avoidable during industrial production

EMPA

During a typical service life, might there be an aging factor other than permeation?

1) What kind?

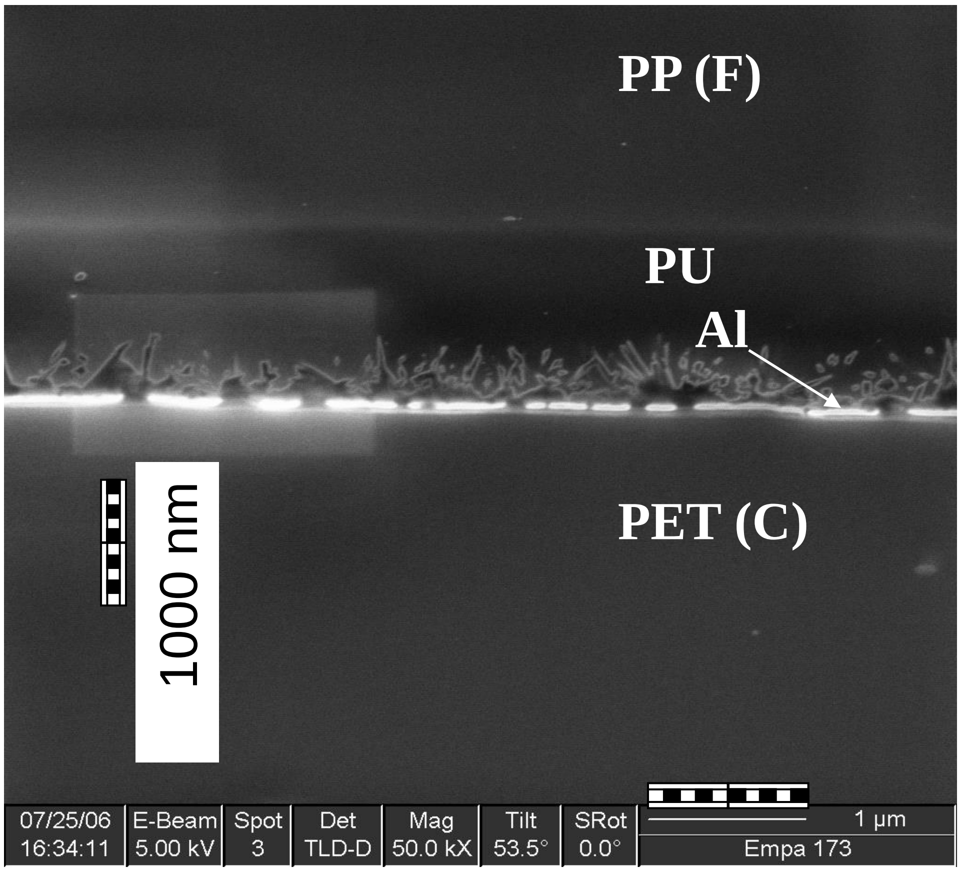
2) Does it reach the failure criteria earlier than permeation?

literature on permeation in VIP :

- Simmler, H., Brunner, S., Energy and Buildings 37 (2005) 1122
- Brunner, S, Simmler H., Vacuum 82 (2008) 700
- Schwab et al, Journal of Thermal Envelope & Building Science, (2005) 28, 293-374

EMPA

After accelerated aging under extreme heat and moisture load



- Barrier layer with defects (corrosion?)

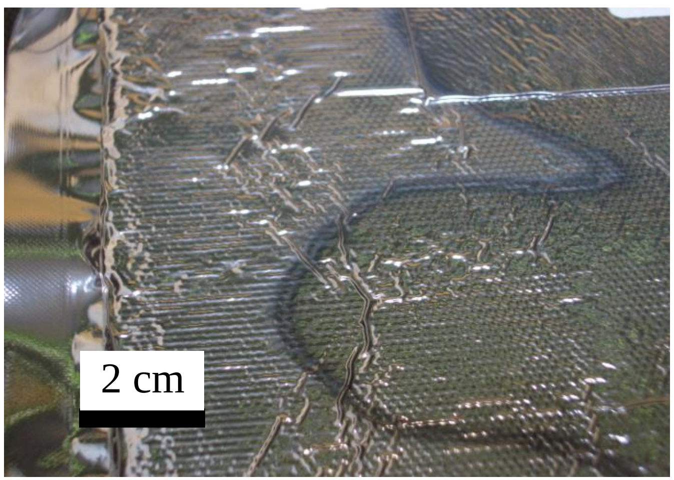
Extremely aged at 65°C, 75%r.h. for 1.9 years

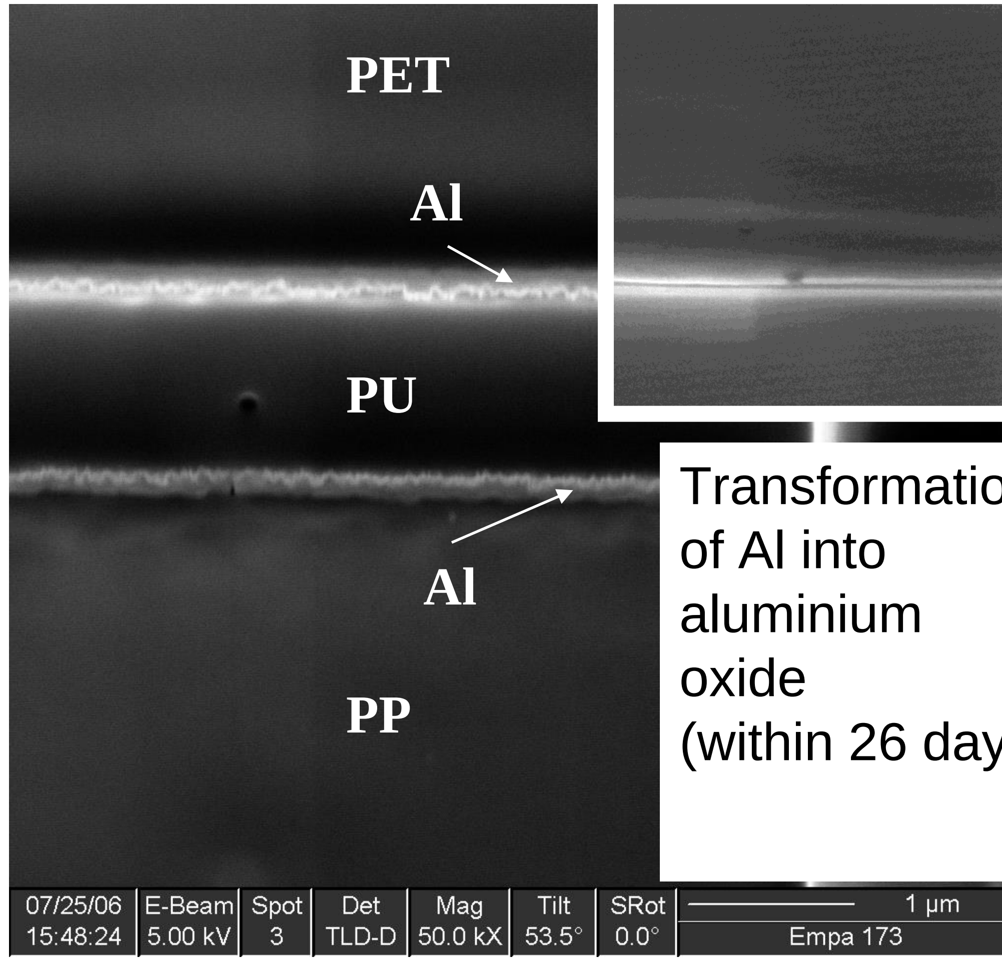
aging continued long after critical pressure was reached in the panel.

S. Brunner et al., Surface & Coatings Technology 202 (2008) 6054

EMPA

High humidity >80%r.H. and temperature >80°C leads to oxidation of aluminium



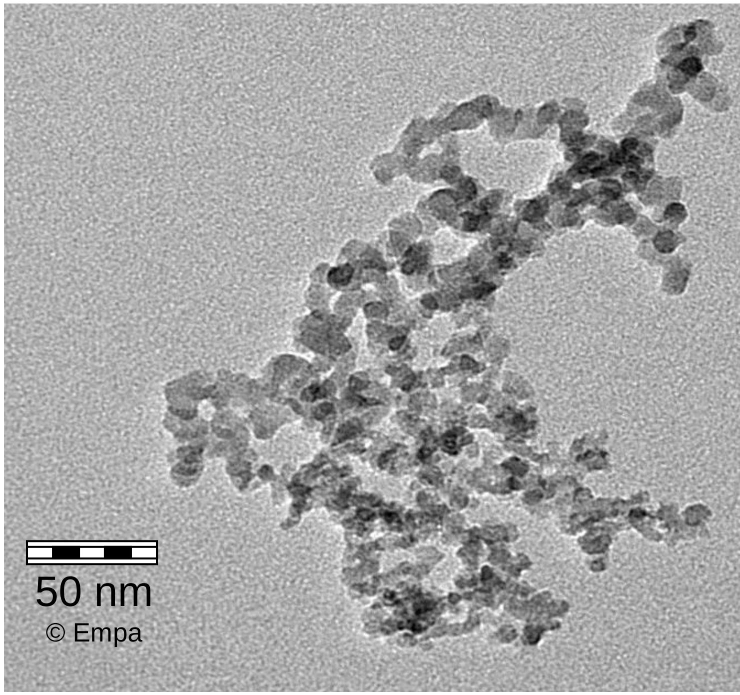


Transformation of Al into aluminium oxide (within 26 days)

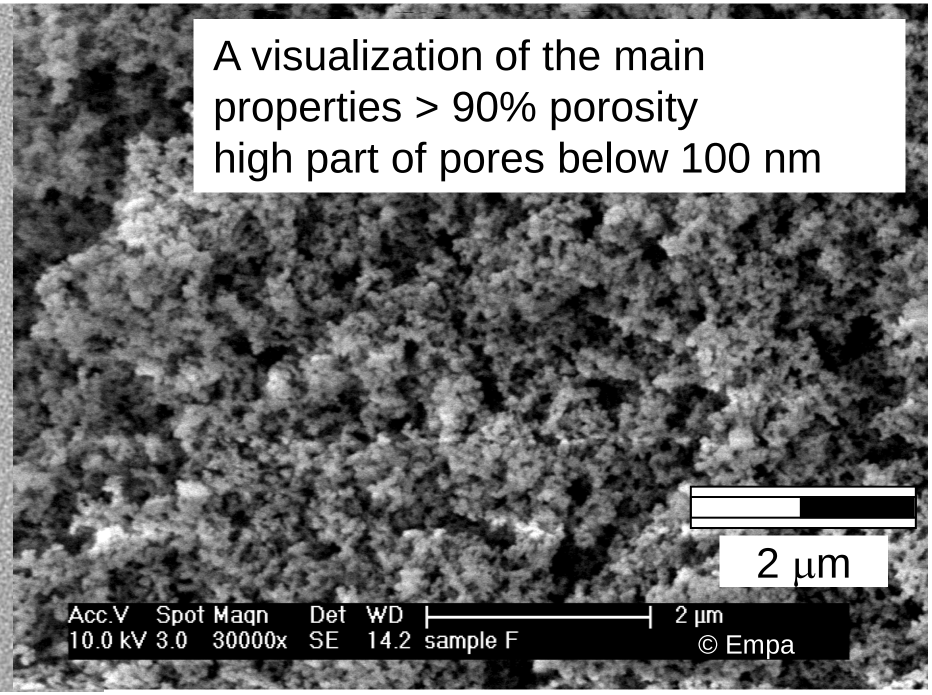
Summary of Focused Ion Beam results

- Damages induced by high moisture and heat load do not appear in the barrier samples naturally aged during 5 years.
- Service Life Prediction based on the permeation rate through the whole VIP is the most appropriate approach for environmental conditions met in buildings in central Europe.
- Corrosion related failure mechanisms will appear much later than permeation related failure mechanism for the described application (as long as pH-conditions are not to extreme e.g. basic water from concrete).

The mentioned statements apply to VIP's with core made of pyrogenic silica.



TEM (Transmission electron microscopy)



SEM (Scanning electron microscopy)

Thanks for your attention