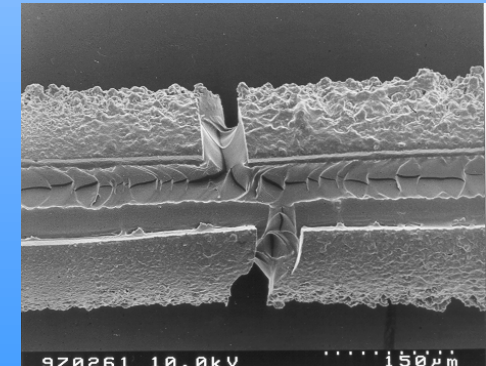
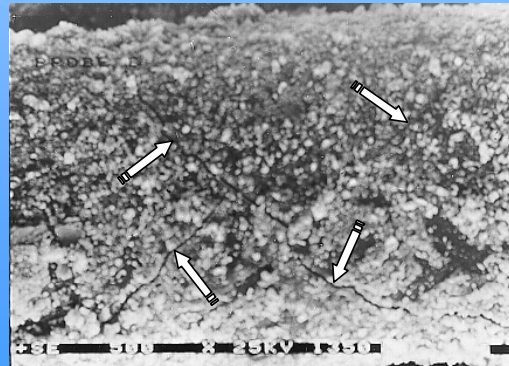

Einflussfaktoren auf die Zuverlässigkeit von Glasfasern und POF

W. Daum

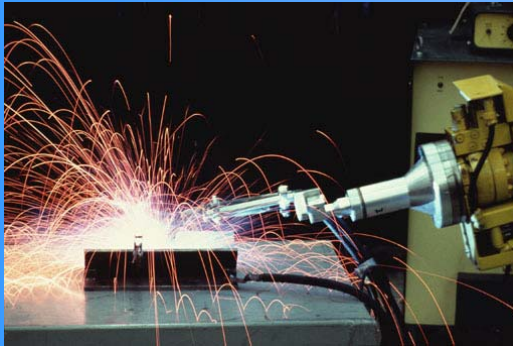
Bundesanstalt für Materialforschung und -prüfung (BAM)

- Introduction
- Industrial and automotive requirements
- Environment - Fibre interactions
- Typical Results
- Conclusions



(Bilder: W. Habel 2000)

Technology competition



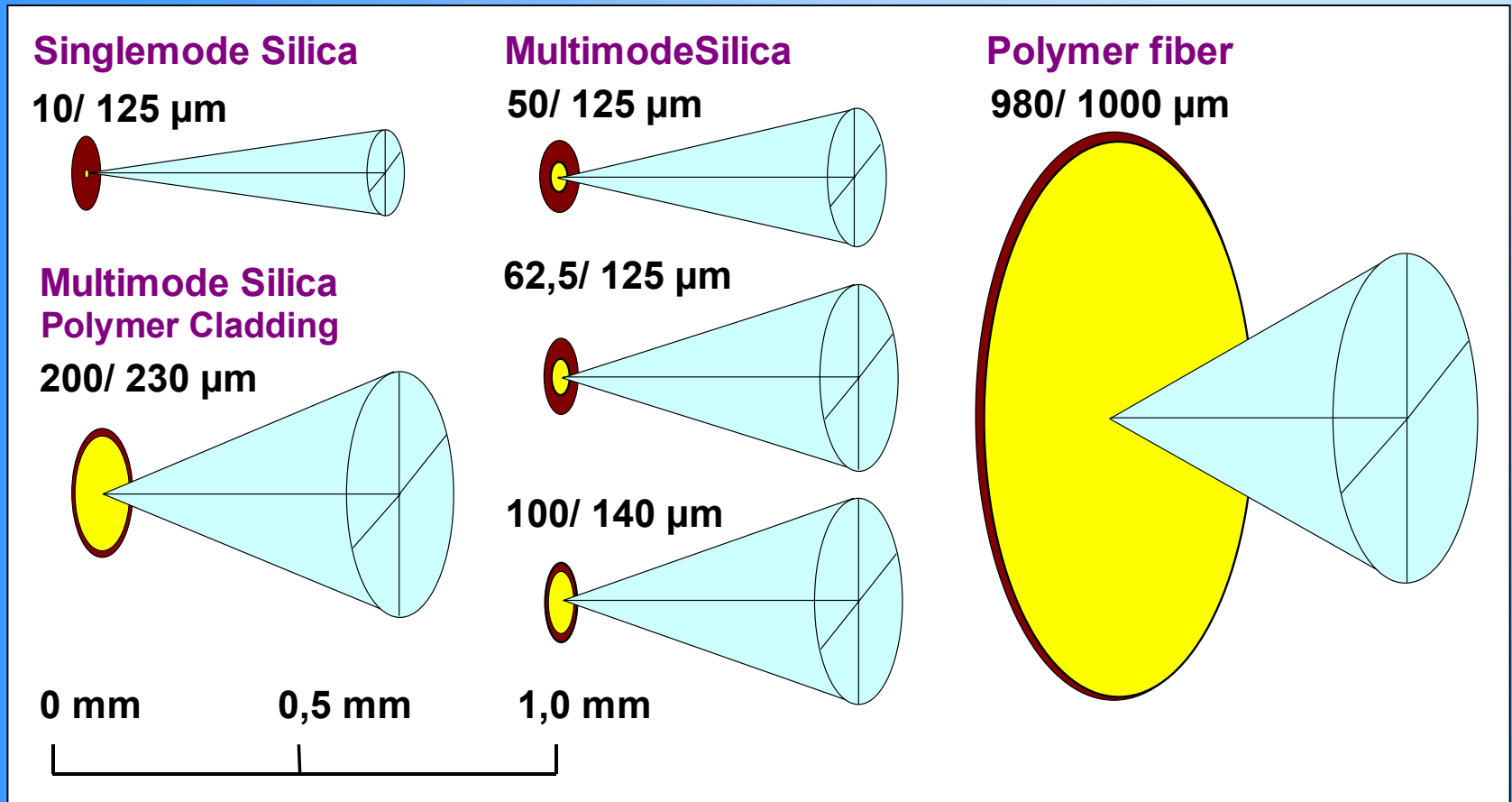
- Robot control
- Machine control
- Sensors

- POF
- PCS
- Silica Fibre bundles



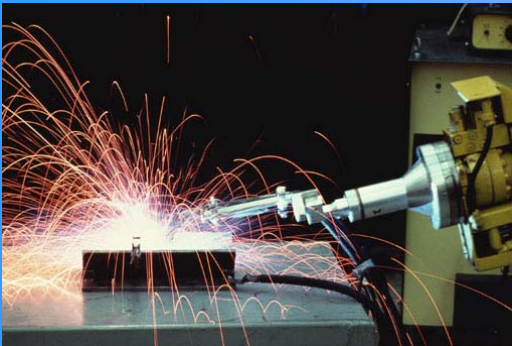
- Short LAN
- Data links in Automotives

Comparison of silica and polymer optical fibres

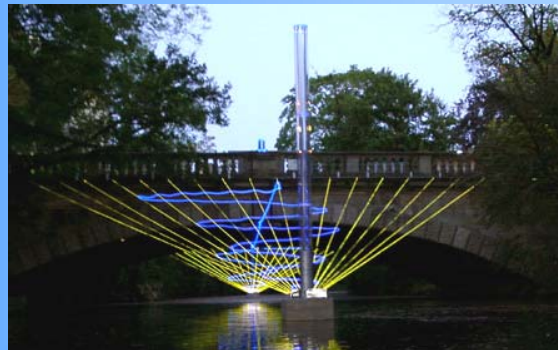


Pictures from: Daum, W., Krauser, J., Zamzow, P.E., and Ziemann, O.: "POF – Polymer Optical Fibers for Data Communication". Springer, Berlin Heidelberg New York 2002

POF application fields



- Robot control
- Machine control
- Sensors



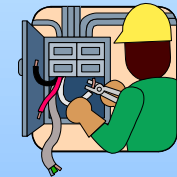
- Short LAN
- Data links in Automotives



- Lighting
- Displays

Environmental stress

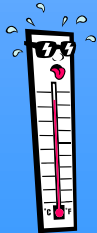
← Mechanical



← Chemical



← Climatic



Typical environmental stress parameters

Mechanical

- Static bending
- Cyclic bending
- Flexing
- Compressive load
- Impact load
- Tension
- Twisting
- Vibration

Climatic / Radiation

- Temperature
- Humidity
- Cyclic climates
- UV- and High Energy radiation
- White frost
- Splash water

Chemical / Biological

- Acids
- Solvents
- Lubricants
- Fuel
- Fuel vapour
- Hydraulic oil
- Brake fluid
- Micro-organisms

very often in combination

Typical automotive stress intensities (acc. to SAE)

Stress parameter	Interior	Underhood	Dashboard
Temperature	- 40 °C +84 °C	- 40 °C +121 .. 204 °C	- 40 °C +113 °C
Humidity	80%RH (+66 °C)		98%RH (+38 °C)
Chemicals (e.g.)	Water Cleaning lye Chemicals Fuel, Oil Brake fluid		



Typical industrial requirements

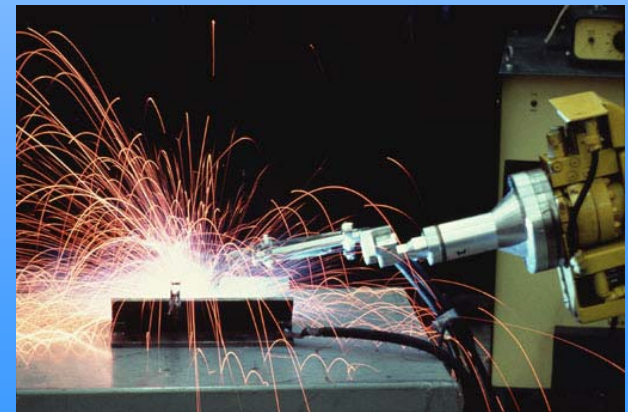
Stress parameter Maximum intensity / substance

Temperature - 20 °C up to +70 °C

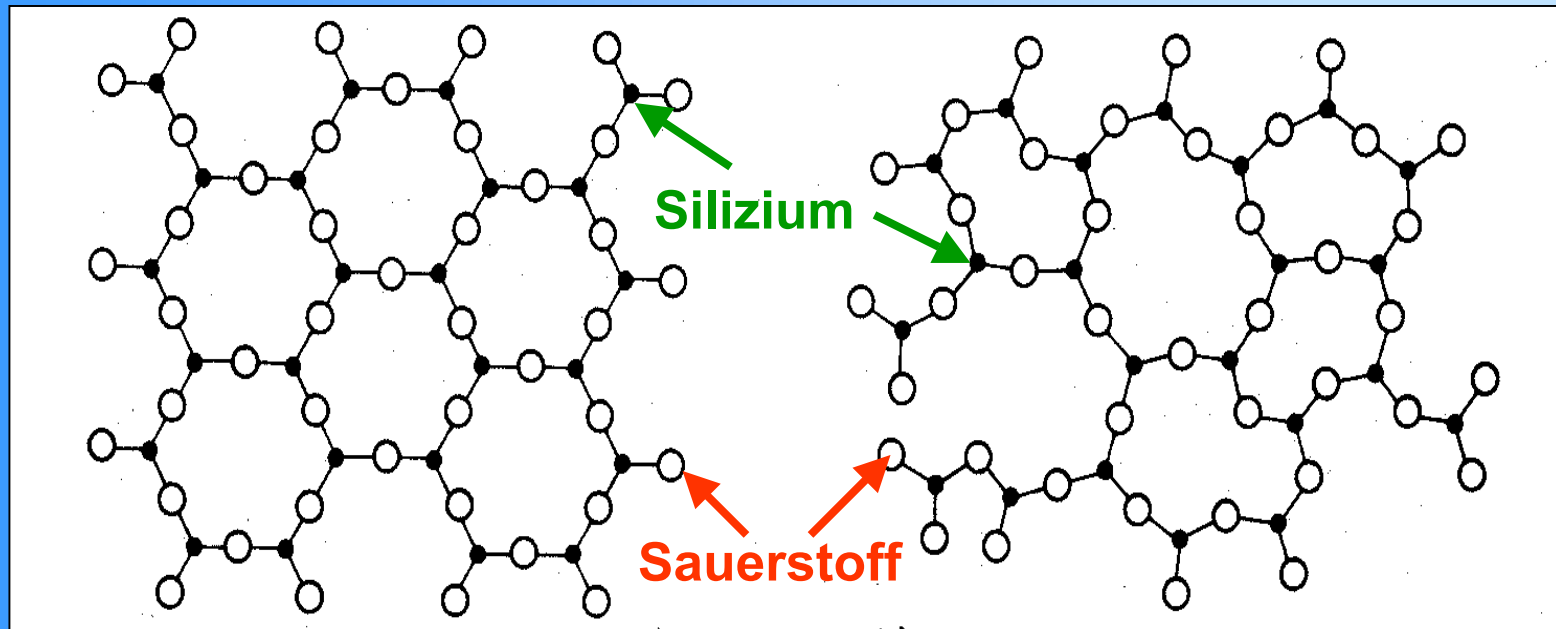
Cyclic bending 10⁴ cycles (±90°) bend radius 40 mm
10⁵ cycles (±90°) bend radius 100 mm

Tension 60 N (short-term)
5 N (long-term)

Chemicals Solvents
Hydraulic oil
Lubricants
Cutting fluid



SiO₂-Netzwerkstrukturen (nach Unger 1982)

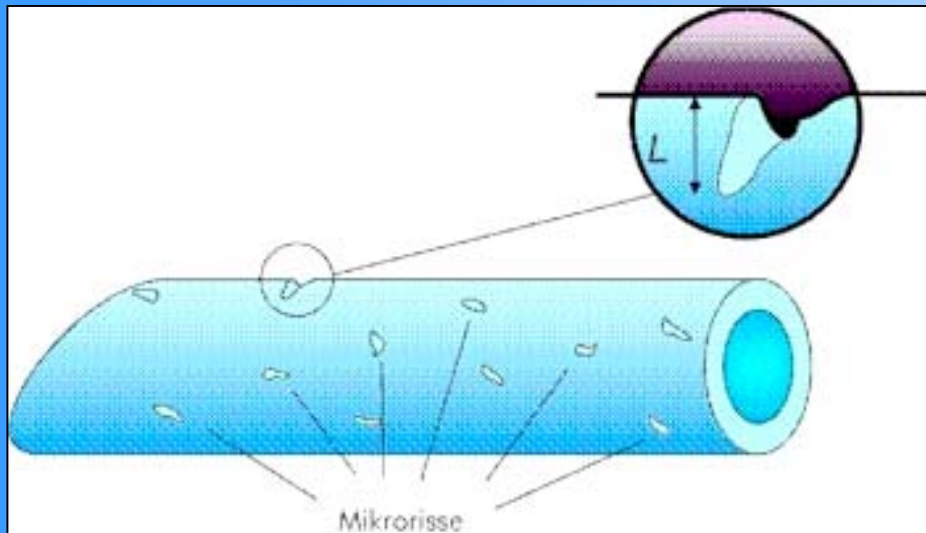


Quarzglas:
Ringstruktur von
Si-O Tetraedern

**unregelmäßiges Netzwerk
des synthetischen
Quarzglases**

Die vierten Valenzen ragen nach oben und unten aus der Zeichenebene heraus.

Strukturschwächung durch Oberflächenstörungen

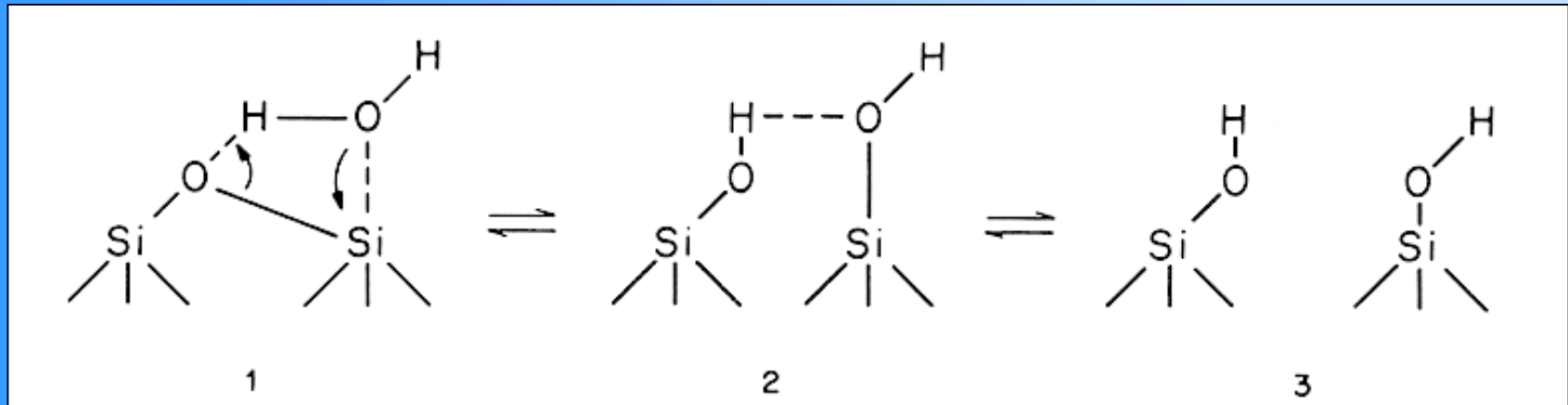


Herstellungsbedingte Oberflächenstörungen in Form von Mikrorissen vergrößern sich unter Einwirkung einer mech. Spannung und/oder Einwirkung bestimmter chemischer Reaktionen

(insbesondere mit Wasser). Dadurch wird die Zugfestigkeit stark herabgesetzt. Die Tiefe und Häufigkeit der Mikrorisse unterliegt einer zufälligen Streuung. Der Bruch einer Glasfaser, ausgehend von diesen Mikrorissen, ist ein zeitabhängiger Vorgang (Risswachstum).

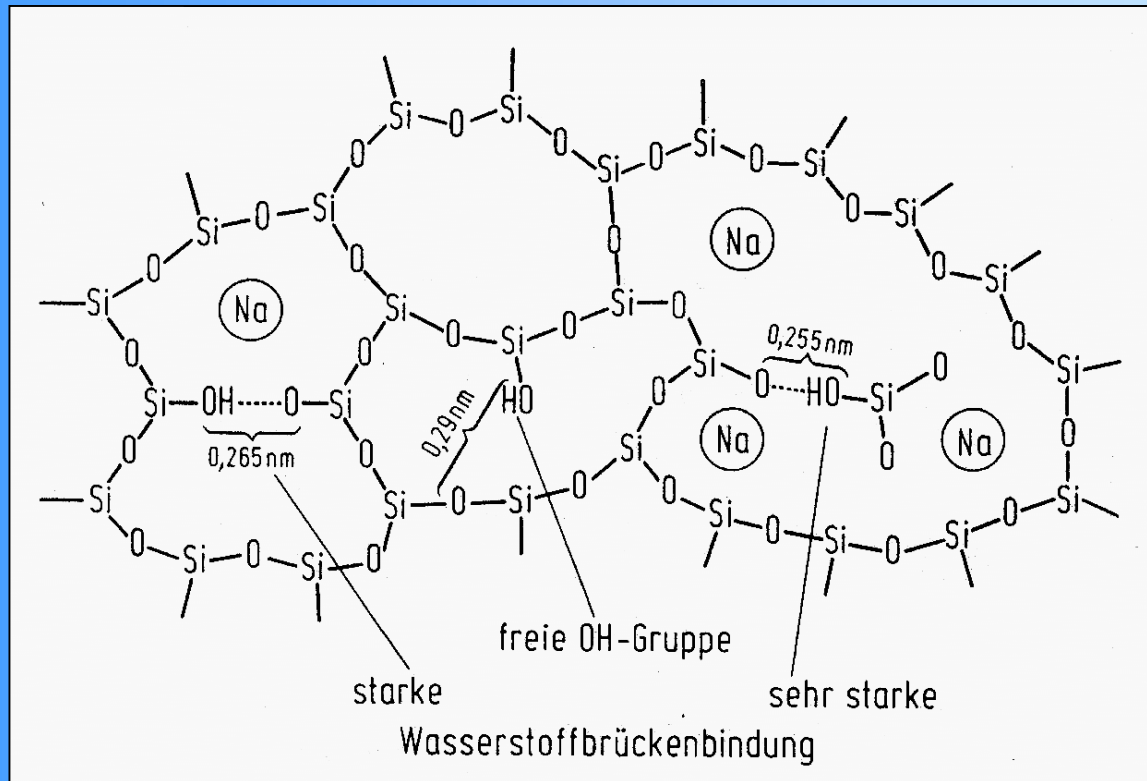
(Bild: Daetwyler-Handbuch der univ. Gebäudeverkabelung)

Strukturschwächung durch H₂O-Reaktion



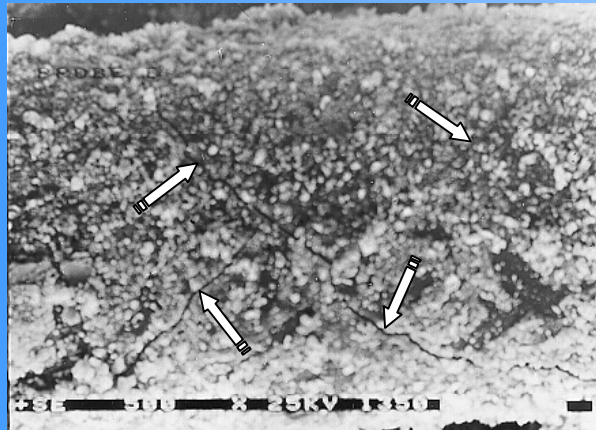
(nach: Michalske u. Freimann 1983 / H. Scholze 1988)

Strukturschwächung durch H₂O-Reaktion



(nach: Michalske u. Freimann 1983 / H. Scholze 1988)

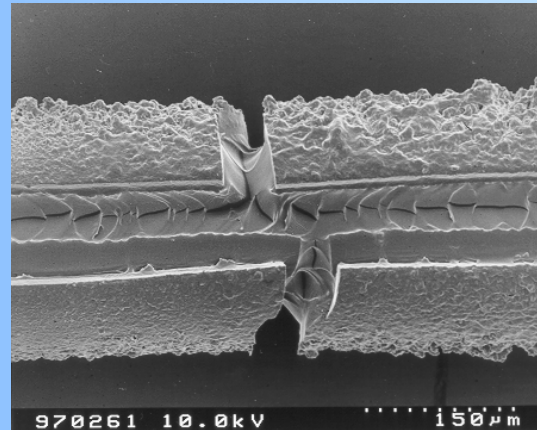
Strukturschwächung durch chemischen Angriff



AC-Coating (Hersteller A)

In PZ-Mörtel eingebettet,
nach 28 Tagen freigelegt.

Die Risse im Coating (Pfeile)
haben eine Rissweite von 870
nm bis maximal 2 μm .

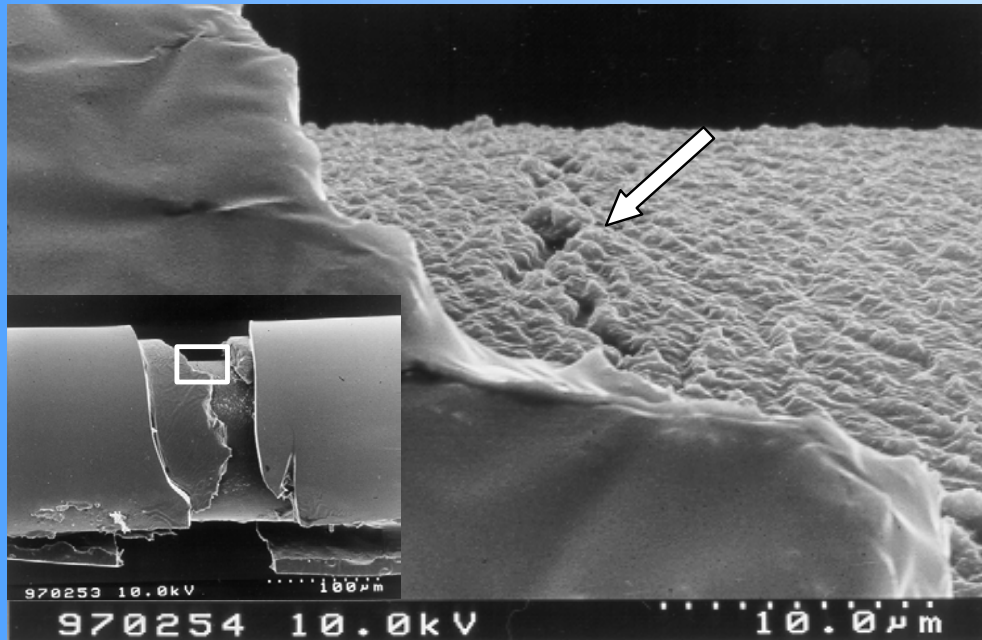


AC-Coating (Hersteller B)

35 Monate in wässrigem
Betonauszug (pH = 11) gelagert,
einmal monatlich wurde die
Lösung bewegt.

(W. Habel 2000)

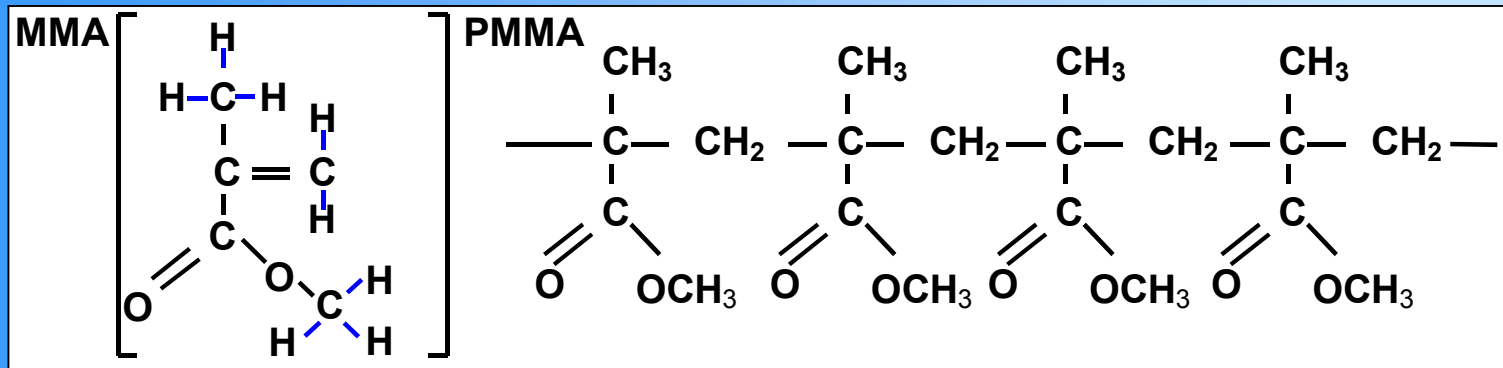
Strukturschwächung durch chemischen Angriff



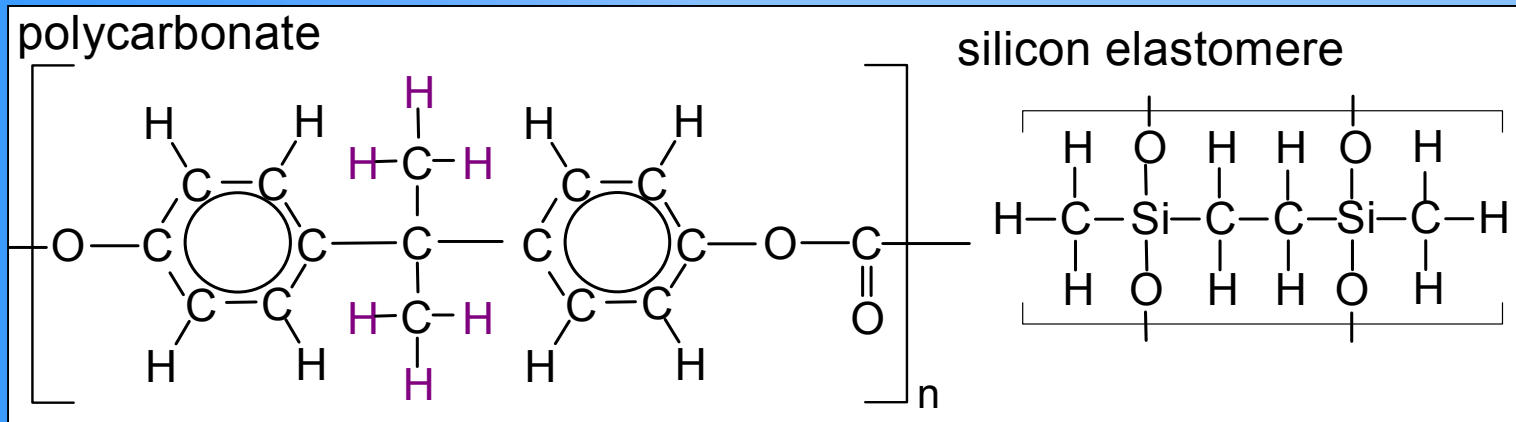
Oberfläche einer optischen Glasfaser
nach 35monatiger Lagerung in
wässrigem Betonauszug (pH = 11)

(W. Habel 2000)

Materials used for POF



High temperatures materials

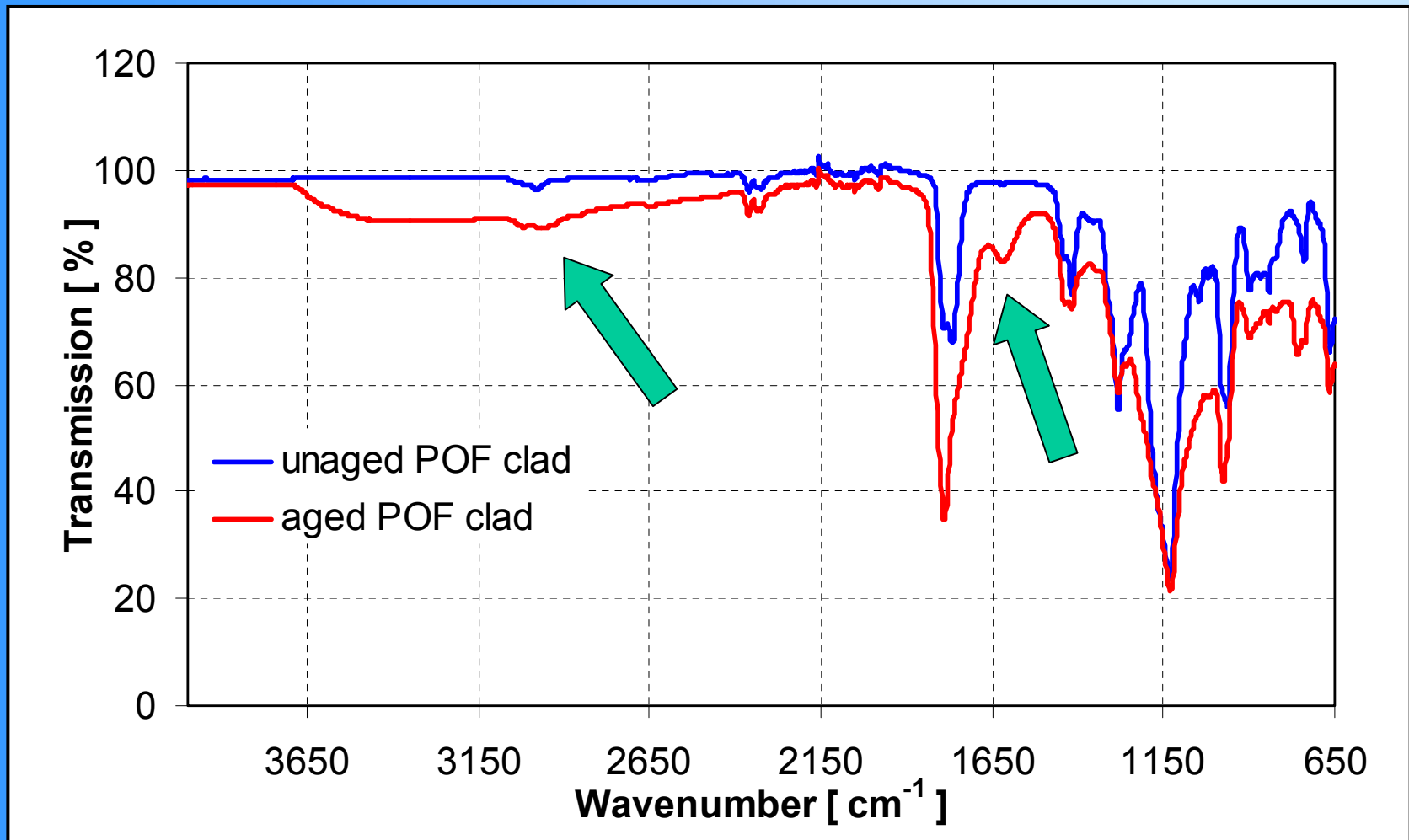


Pictures from: Daum, W., Krauser, J., Zamzow, P.E., and Ziemann, O.: "POF – Polymer Optical Fibers for Data Communication". Springer, Berlin Heidelberg New York 2002

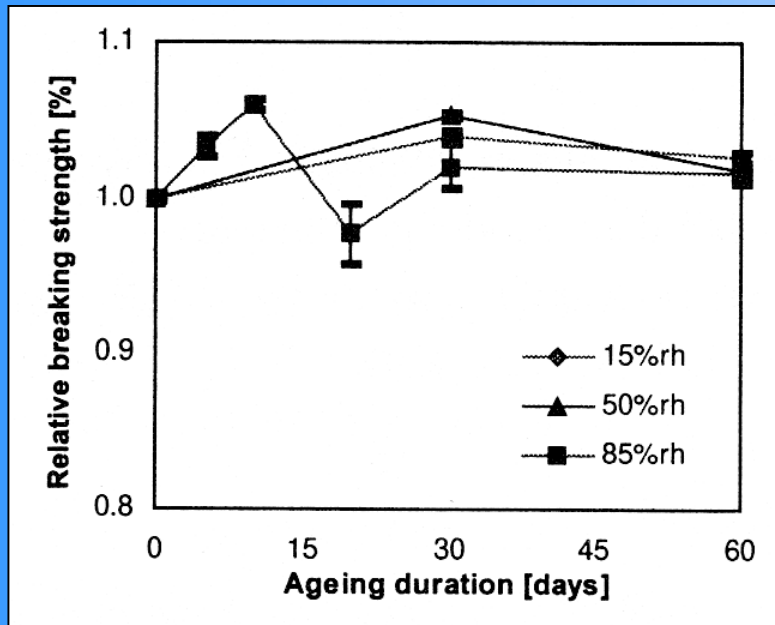
Loss mechanisms of POF (acc. to T. Kaino)

Intrinsic loss factors	Absorption	<ul style="list-style-type: none">• High harmonics of CH absorption
	Scattering	<ul style="list-style-type: none">• Electronic transitions• Rayleigh scattering
Extrinsic loss factors	Absorption	<ul style="list-style-type: none">• Transition metals• Organic contamination• Absorbed water
	Scattering	<ul style="list-style-type: none">• Micro-voids, -cracks• Micro-inclusions• Fluctuation of core diameter• Core-cladding boundary imperfections

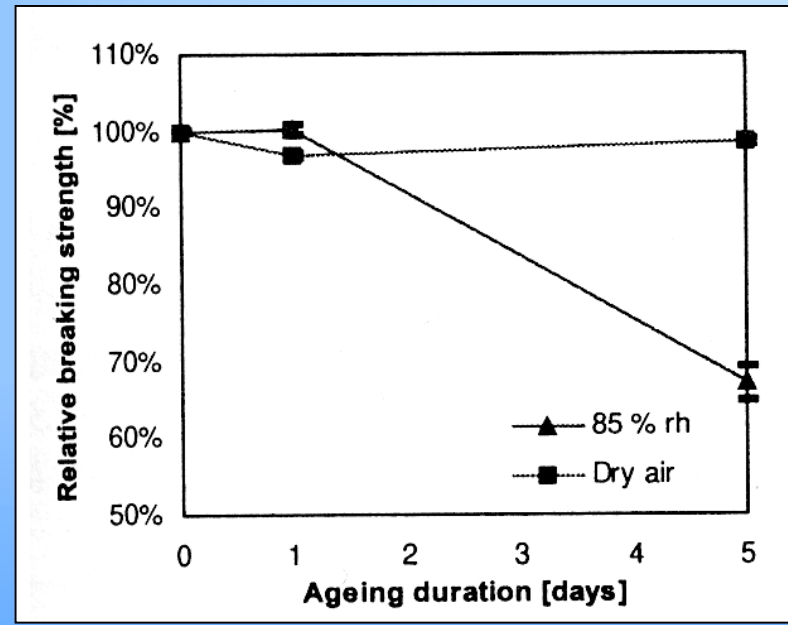
Fourier transform infrared spectroscopy (FTIR)



Breaking strength of acrylate-coated fibres



Fibre A at 85 °C

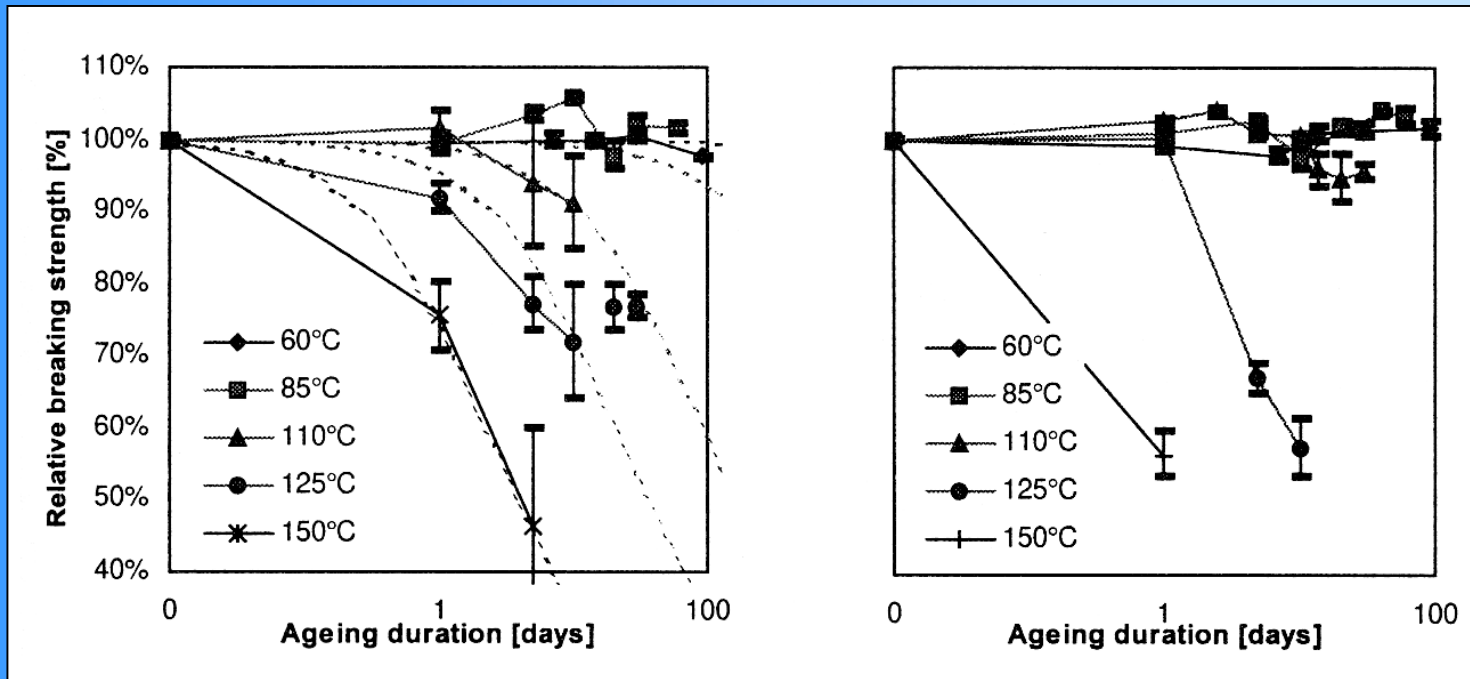


Fibre B at 125 °C

Testing method: dynamic tensile testing acc. to IEC 60793-1-3

(P. Mauron et. al. 1998)

Breaking strength of acrylate-coated fibres



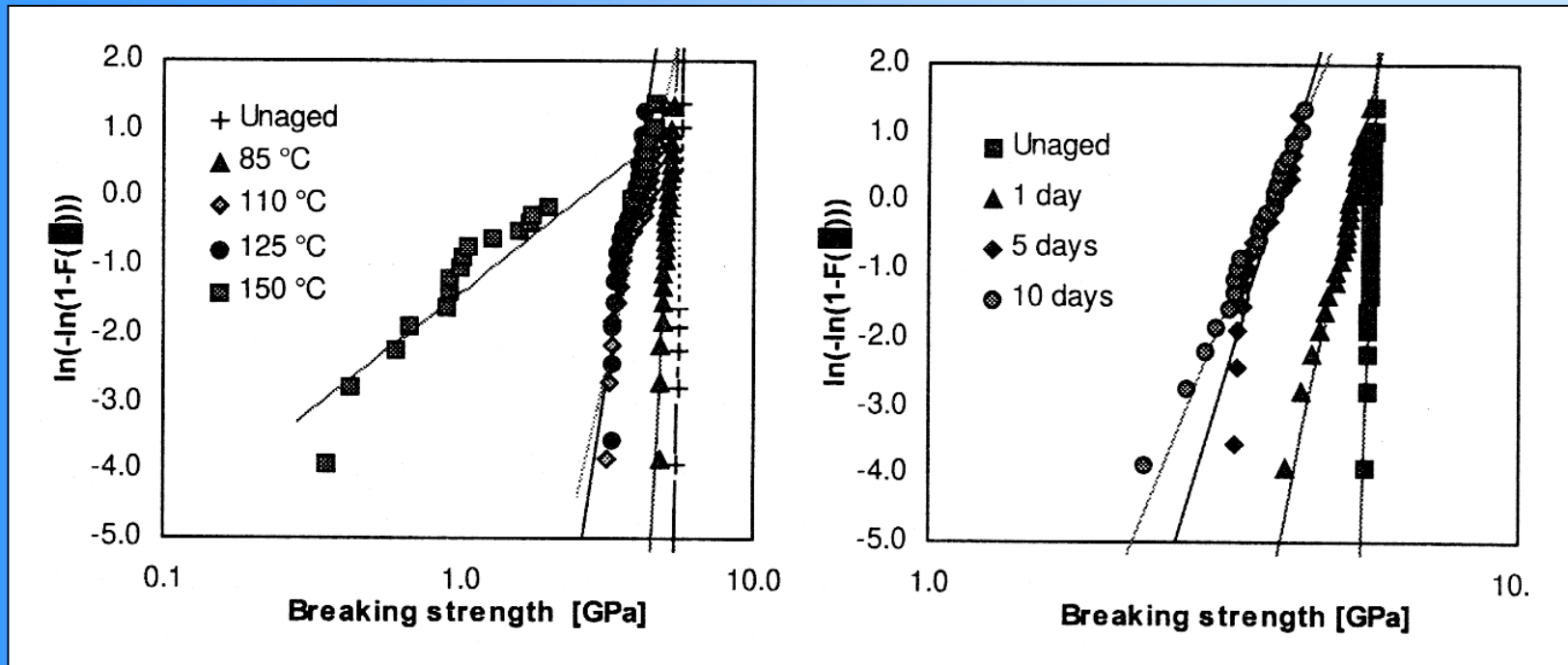
Fibre A at 85%RH

Fibre B at 85%RH

Testing method: dynamic tensile testing acc. to IEC 60793-1-3

(P. Mauron et. al. 1998)

Weibull plots of acrylate-coated fibres



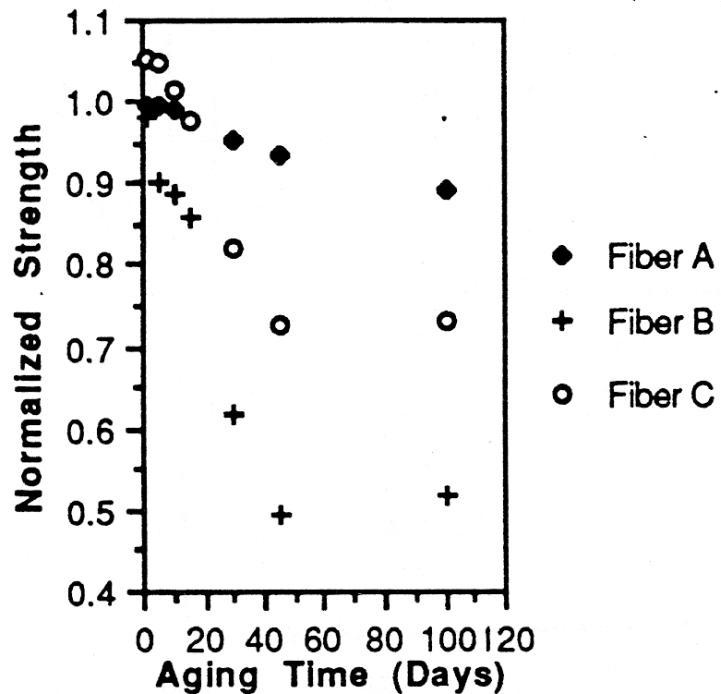
Fibre A after
5 days of ageing

Fibre A at 125 °C

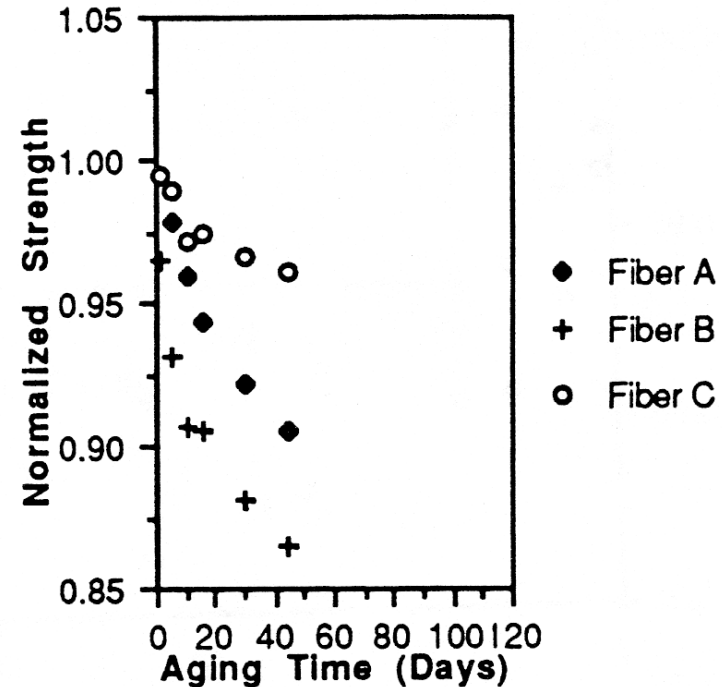
(P. Mauron et. al. 1998)

Breaking strength of telecommunication fibres

85°C Water Aging
Strength vs Aging Time

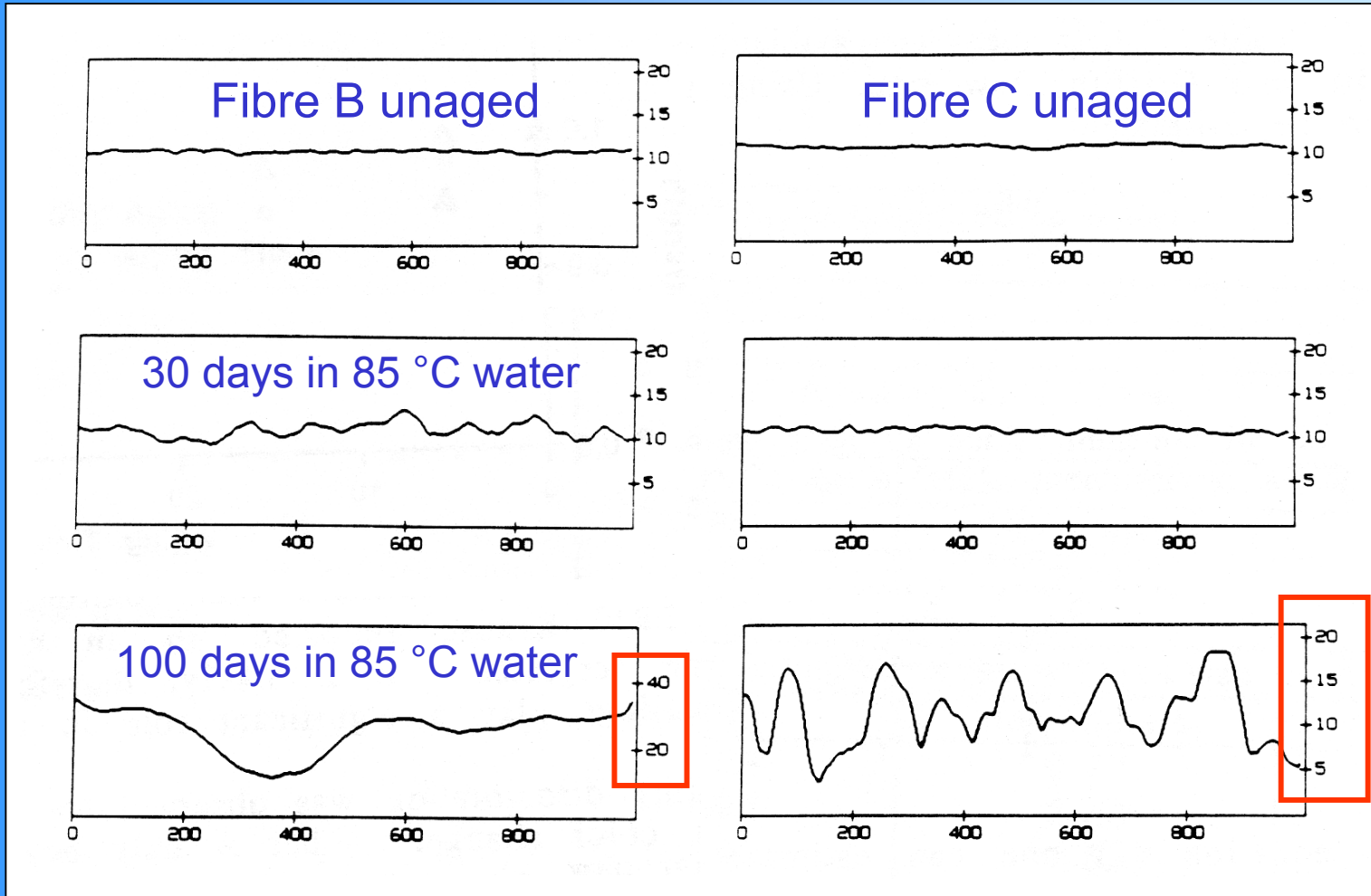


85°C @ 94% R.H. Aging
Strength vs Aging Time



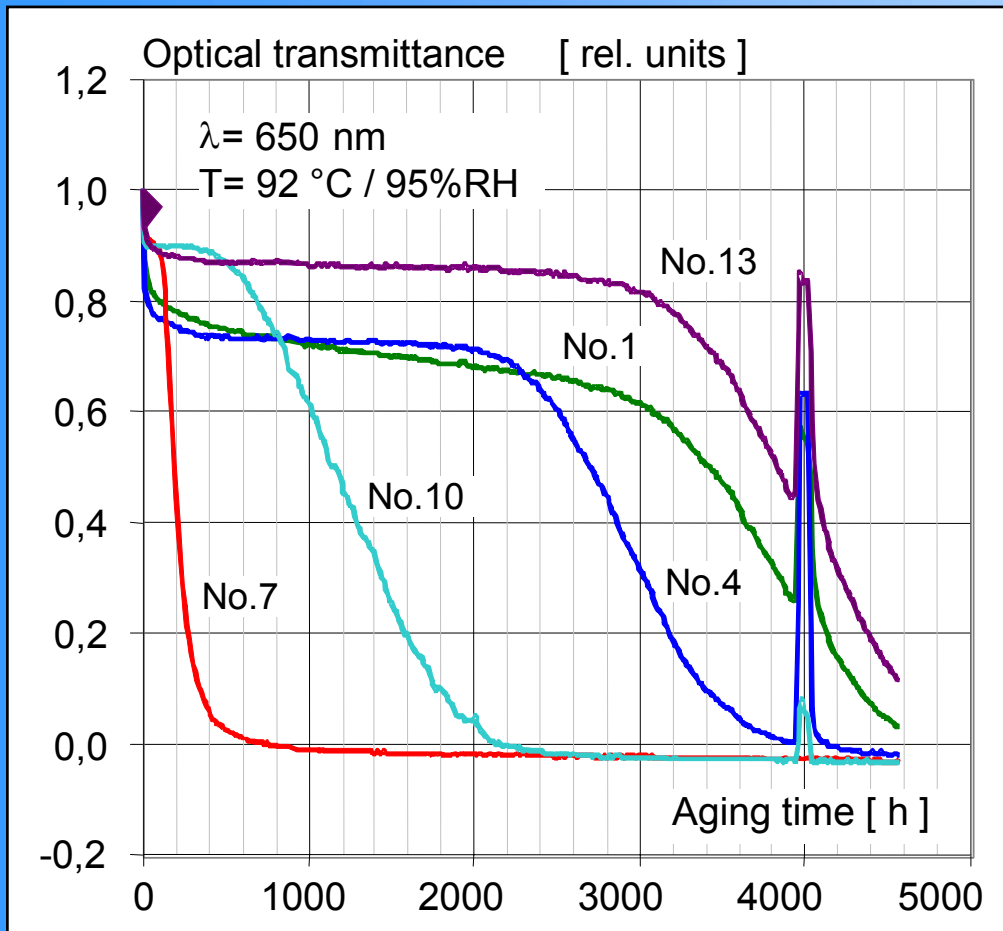
(T. Kennedy et. al. 1991)

AFM images of unaged and aged fibres

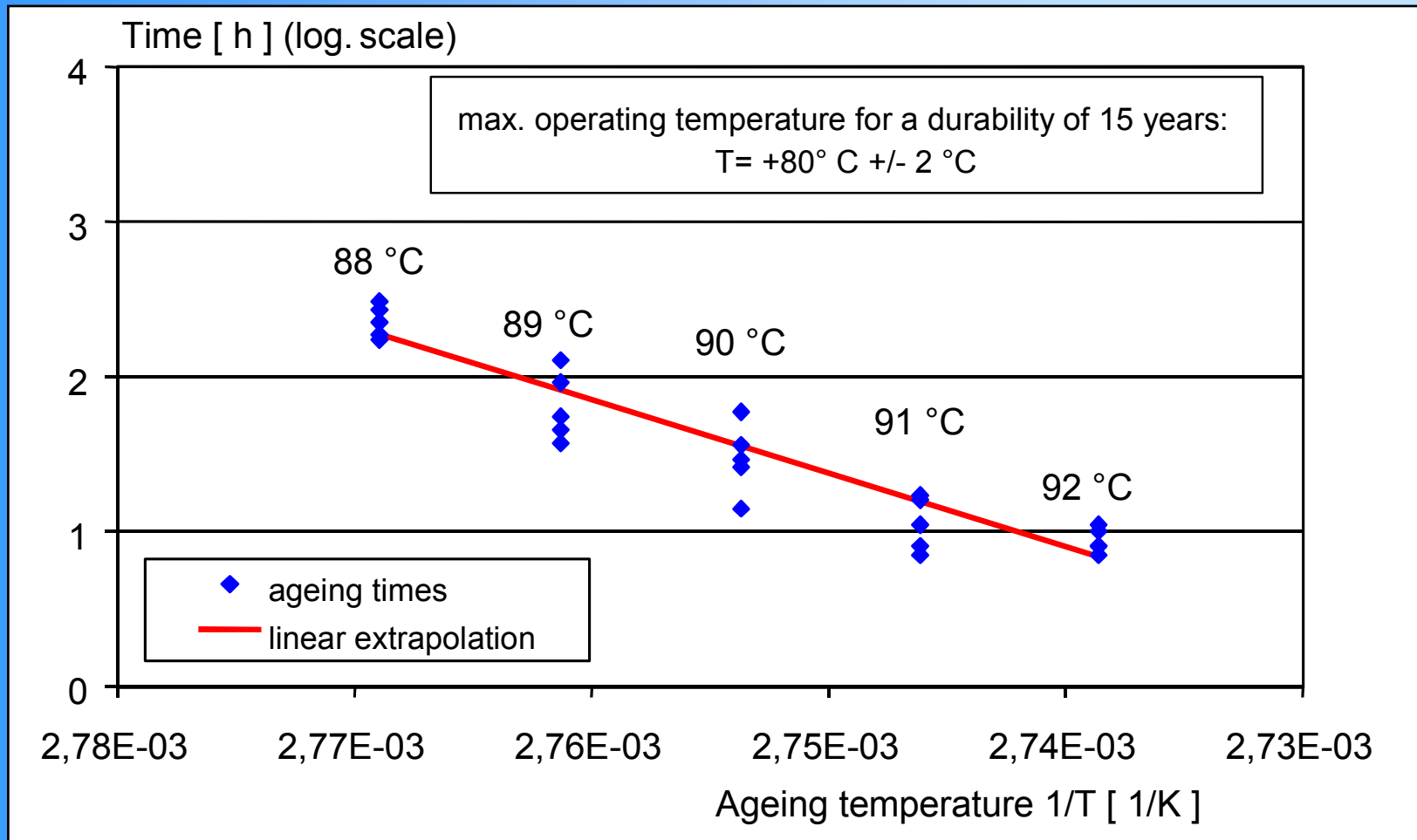


(T. Kennedy et. al. 1991)

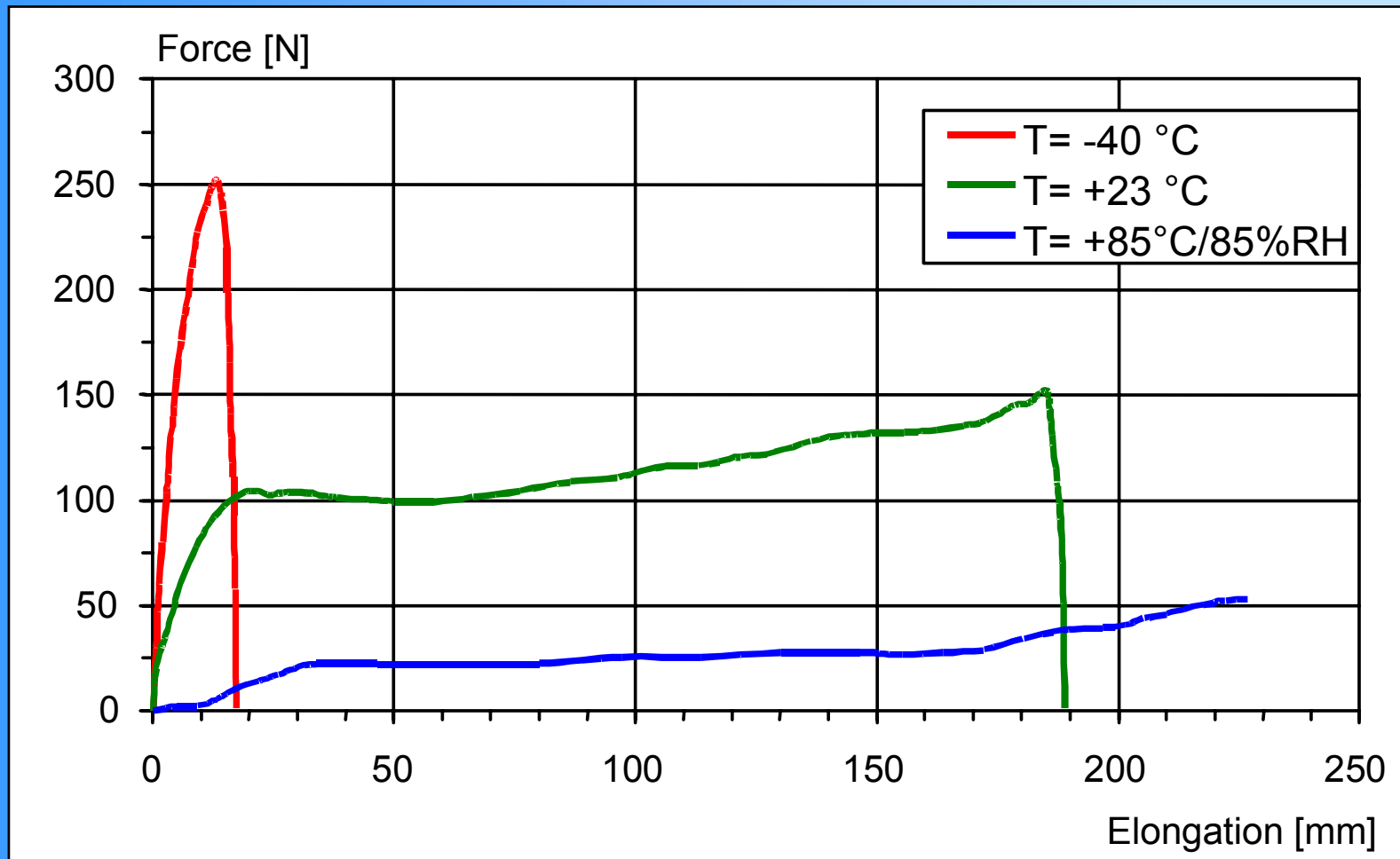
Durability of different jacketed step-index-POF



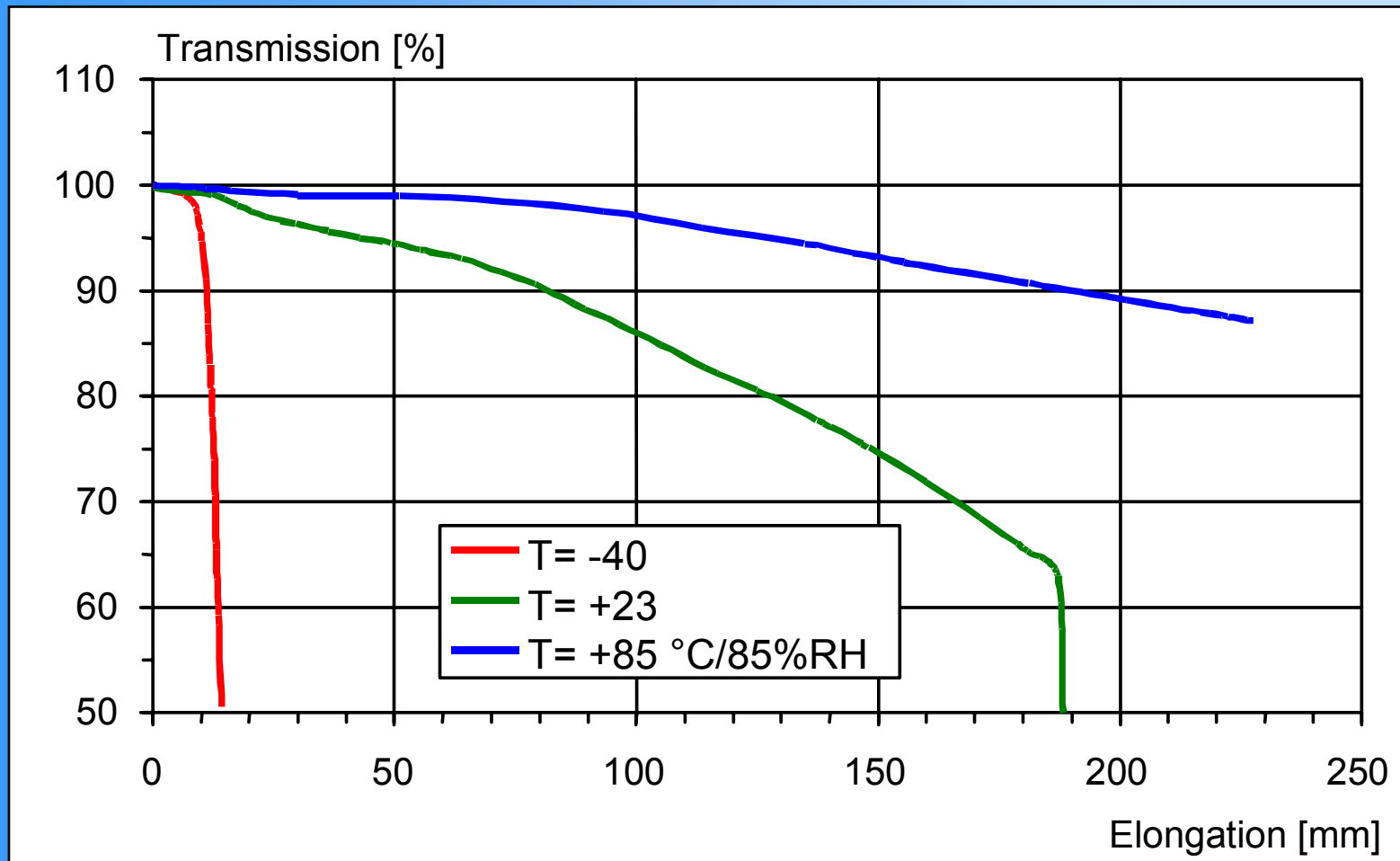
Durability of a PMMA-POF without jacket



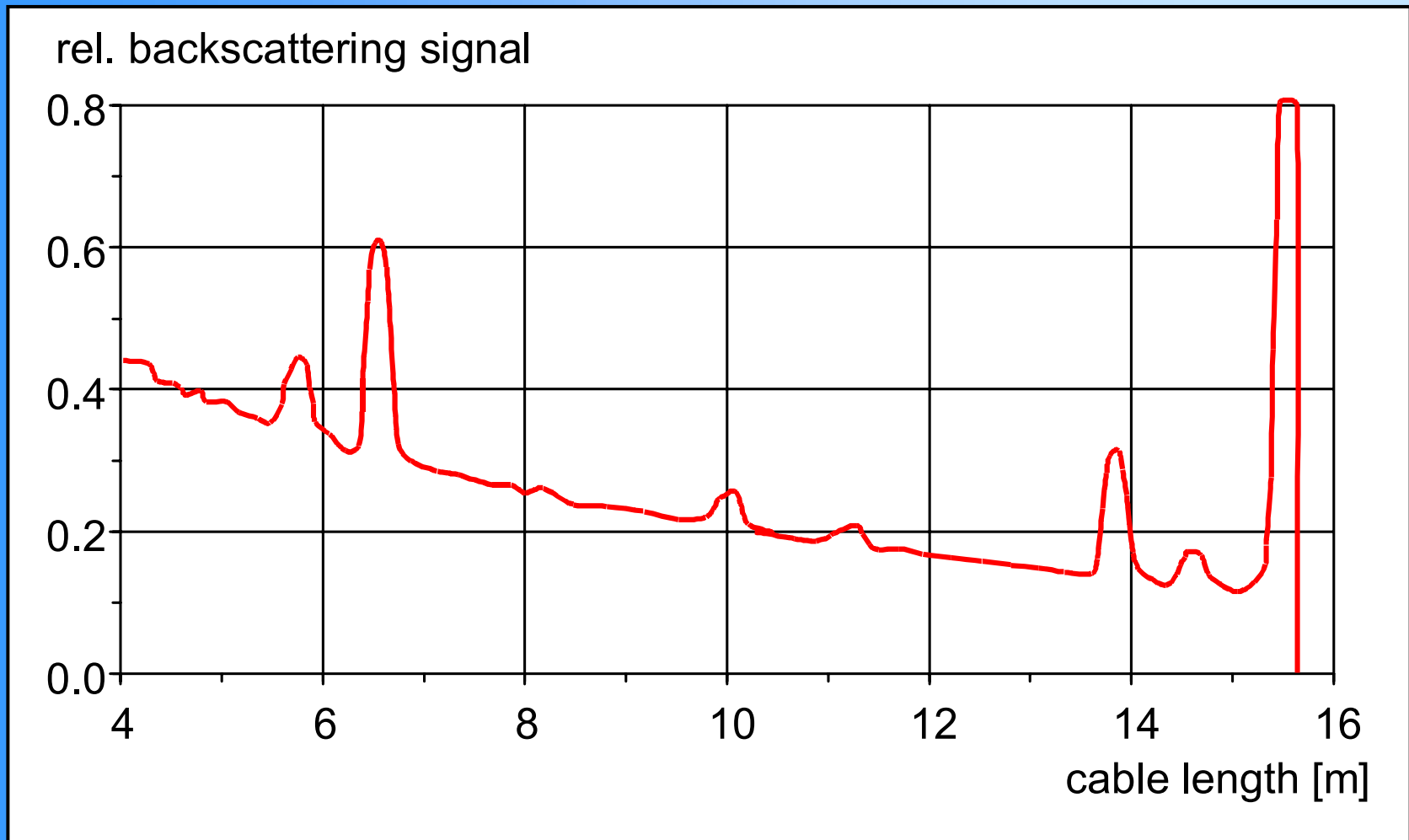
Optical transmission under tensile stress



Optical transmission under tensile stress



Backscattering of a POF cable with several imperfections



- **Silica fibre: degradation of fibre strength as a function of time, temperature and environment (especially water)**
- **POF: degradation of attenuation as a function of time, temperature and environment (especially water).**
- **Based on the main degradation mechanism and field of application, specific reliability tests must be carried out (e.g. vibration test of aged silica fibres with regard to automotive applications).**