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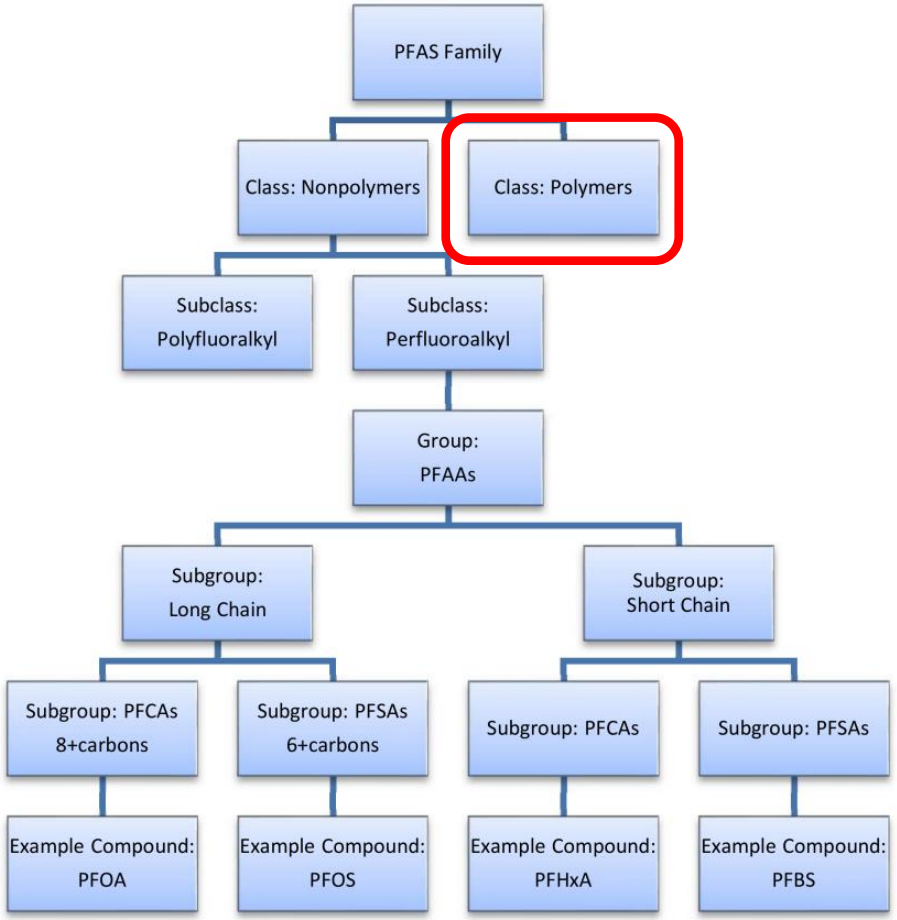
06.11.2024

Evaluation of Options for Substituting PFAS - PFASub

Christian Beinert

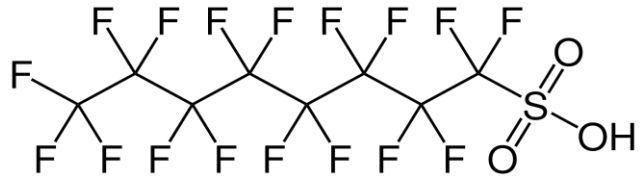
Per- und Polyfluoroalkyl Substances

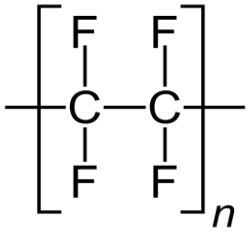
Overview of major families of PFAS



Int. J. Environ. Res. Public Health **2021**, *18*(20), 10900; https://doi.org/10.3390/ijerph182010900

Perfluorosulfonic acid (PFOS)





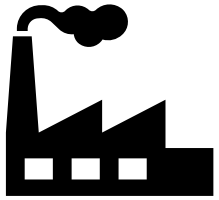
PTFE is **nontoxic** … and is **not metabolized**, physiologically neutral (FDA approved), … but **persistent**

Broad range of very different products!

Polyfluoroethylene in Reference Module in Biomedical Science, 2022, https://doi.org/10.1016/B978-0-12-824315-2.00270-0

Fluoropolymers and Fluorelastomers

Potential risks of emissions along the product & potential measures



Manufacturing

Release of monomers or low-molecular PFAS

- Optimized procedures
- Environmental control & capturing methods

Use

Release of degradation products and additives during processing and use

- Efficient procdure for assessing ability to substitute PFAS
- **Substitution where possible**
- Use of fluorpolymers in technical demanding application where substitution is not possible → long-term R&D

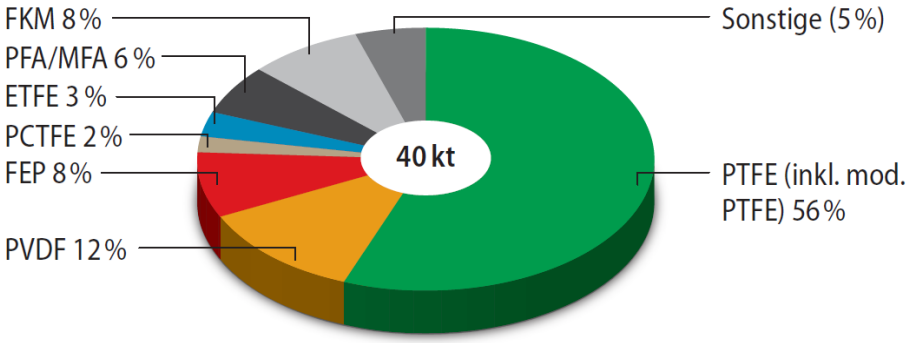
End-of-Life

Release during incineration or disposal

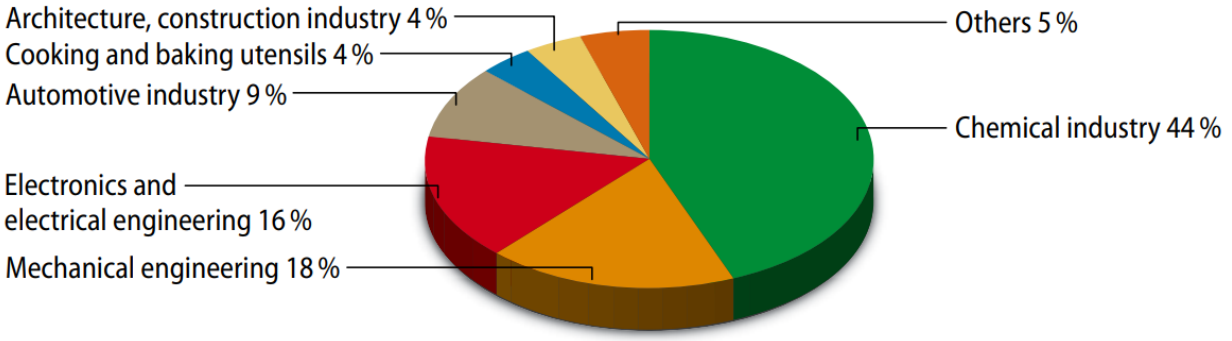
- Waste management
- Circularity (mechanical/chemical)

Fluoropolymers and Fluoroelastomers

Market And Industrial Sectors



M. Schlipf, Fluorkunststoffe: Enabler für die Wasserstoffherstellung und Elektromobilität Polymere für die schwierigen Fälle, Kunststoffe 10/2022, 114 – 118.



R. Krämer, M. Schlipf, Fluoropolymers, Kunststoffe international 10/2016, 82 – 86.

- ca. **40 kt** fluoropolymers and elastomers processed in Europe (2020)
- The chemical industry, mechanical engineering, eletronics and the automotive industry are the main purchaser of PTFE in Europe

Fluoropolymers and Fluoroelastomers

Wide range of applications to fulfill demanding and highly specialized (sets of) requirements

Industry / application area	Key properties	Typical uses
Chemical / petrochemical industry	Chemical resistance, thermal stability, cryogenic properties	Gaskets, vessel liners, pumps, valves, heat exchangers, …
E&E	Low dielectric constant, high dielectric breakdown voltage, thermal stability, flame resistance, …	Wire and cable insulation, connerctors, optical fibers, printed circuit boards, …
Automotive/aircraft	Low coefficient of friction, good mechanical properties, cryogenic properties, chemical resistance, low permeation	Seals, O-rings, hoses in power steering, …
Medical	Low surface energy, stability, purity, chemical resistance, …	Heart patches, cardiovascular grafts, ligament replacement, …
Polymer additives	Low coeffecient of friction, flame resistance, abrasion resistance, antistick properties	Processing Aids (polyolefins), additives for inks, coatings, lubricants, anti-dripping agents
Semiconductor industry	Chemical resistance, high purity, antiadhesion, insulation, barrier properties, thermal stability	Binders for electrodes, separators, membranes, gaskets, coatings for wind mill blades, …

Chem. Eur. J. 2018, 24, 18830 – 18841

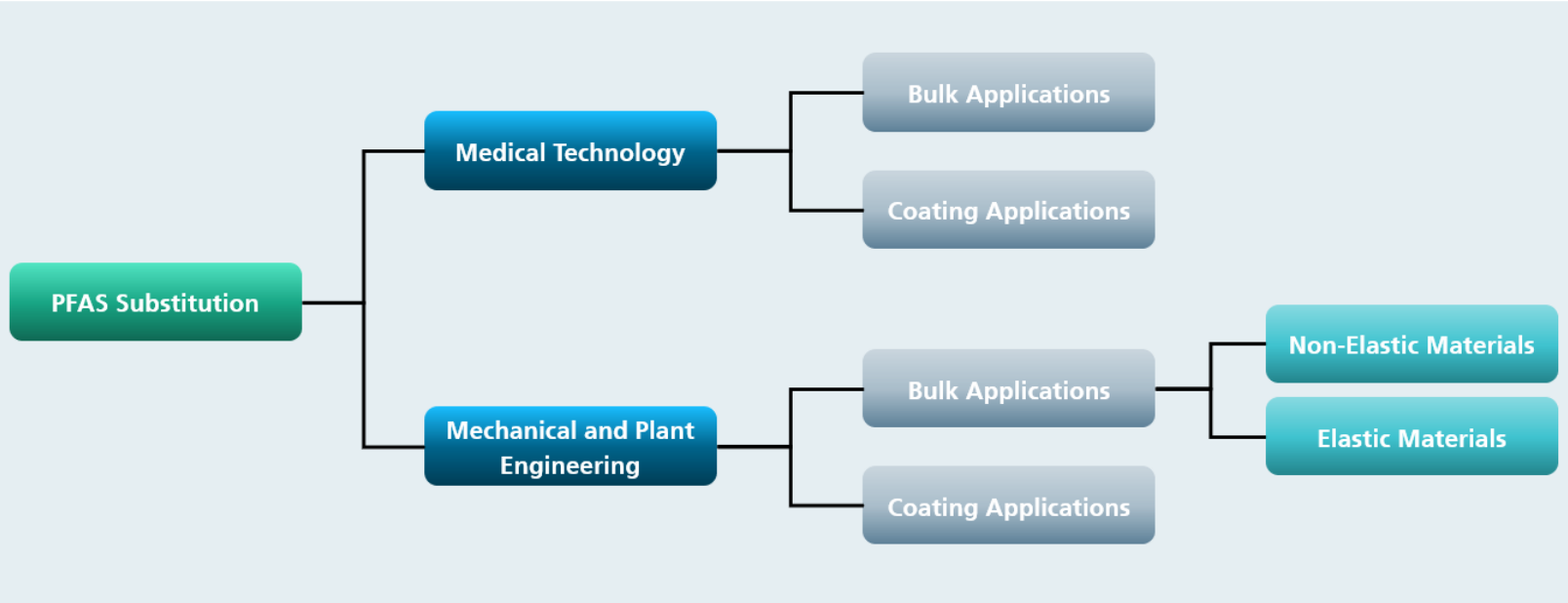
Combination of properties makes the difference

The unique combination of chemical stability, thermal stability, tribology, durability and mechanical properties makes it difficult to substitute PFAS in industrial and medical applications.

- PFAS are resistant to aggressive chemicals and acids. Furthermore, their ability to withstand hydrolysis processes is crucial for many applications.
- PFAS offer remarkable long-term stability: they maintain their performance over an extended period of time without significant degradation.
- The temperature stability of PFAS allows them to be used in extreme temperature environments without losing their functionality.
- PFAS are characterised by their high sliding and non-stick properties, which are essential in many areas, including food processing and medical technology.
- In some applications, particularly in medical technology and pharmaceuticals, biocompatibility is crucial.

Overview PFASub

- Industrial joint project
- 21 participants with different specific requirements
- Focus commercially available materials for generic profiles
  - High-performance polymers
  - Coatings
  - Elastomers
- Consideration of materials in scientific literature
- Discussion about substitution materials with 24 external companies (material manufacturers, research institutes)
- 16 external presentations



Overview of Materials

Current Status of Research vs. Fluoropolymers

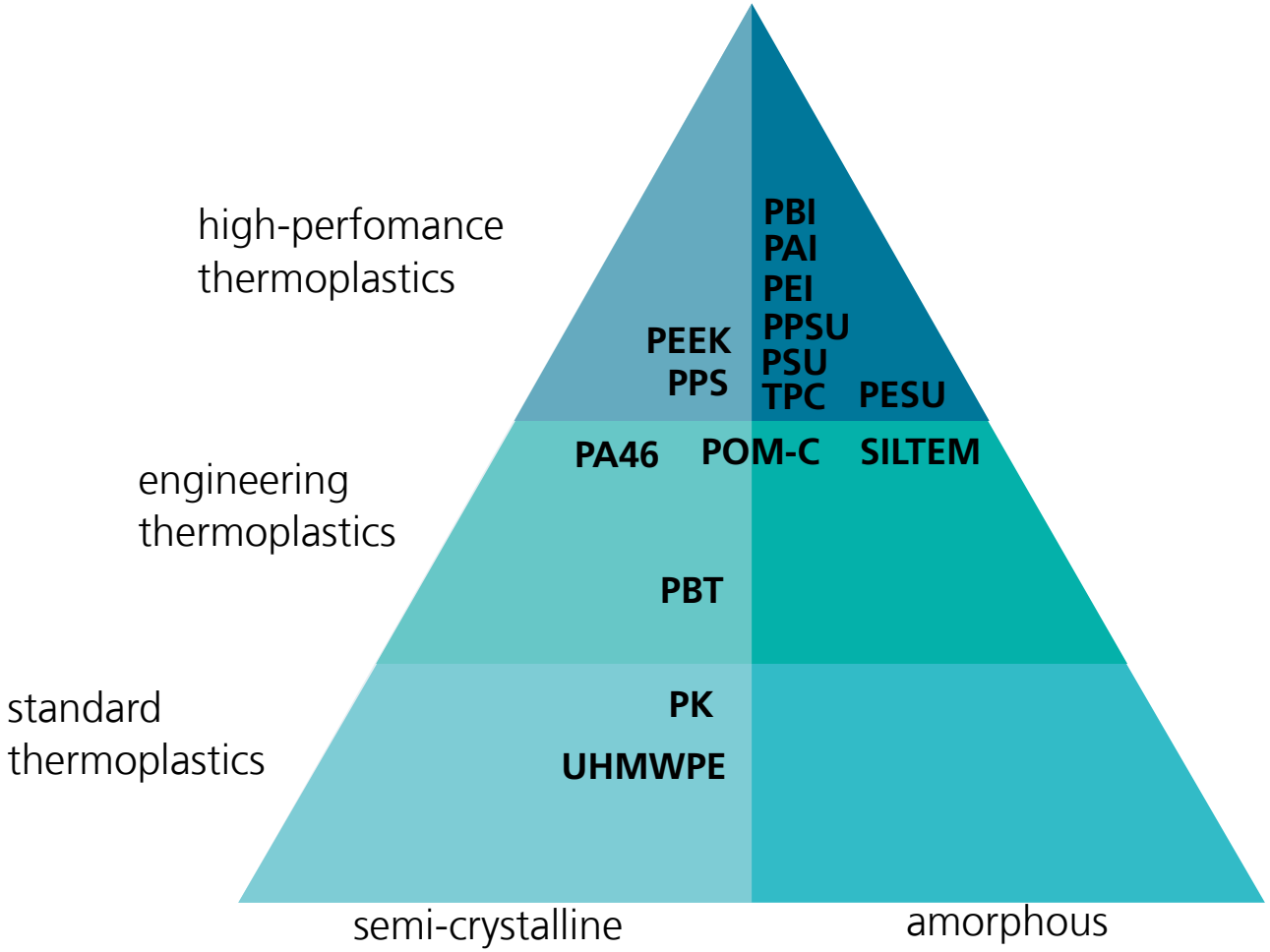
Non-elastic materials

Fluoropolymers

- PTFE
- PFA

Selected potential substitution materials

- PEEK
- PPSU
- PEI
- UHMWPE



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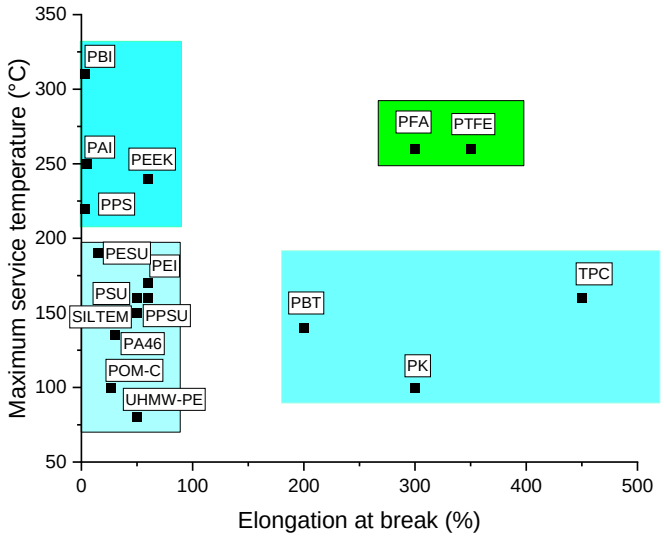
Fluoropolymers and Fluorelastomers

Substitution option: High performance polymers

- might be an alternative in **certain applications** *(depending on the specific requirements for thermal, mechanical, electrical, tribological and other properties)*

- need to be **evaluated for the specific application** (and key properties)



	PTFE	FEP	PI	PEEK	PPS
Maximum continuous use temperature [°C]	260	200	300	240	230
Minimum continuous use temperature [°C]	-200	-200	-270	-50	
Elongation at break [%]	140 – 500	300 – 350	2 – 5.9		4
Tensile Strength [MPa]	20 – 40	25 – 30	37 – 81	100	120
Comparative tracking index [V]	> 600	> 600	< 175	< 175	
Water absorption at 25°C / 50 % rh [%]	< 0,01	< 0,01	< 2,8	0,04	< 0,05
…					

Fluoropolymers

Substitution Options: Limits – Example: Chemical and temperature resistance

- However: in **many other cases it is <u>not</u> possible to substitute a PFAS material by another (polymer) material** *(without re-designing components or parts and/or to change production processes)*

	HCl	HCl	H_2SO_4	H_2SO_4
Concentration [%]	20	40	96	96
Temperature [°C]	100	100	25	100
PTFE	**A**	**A**	**A**	**A**
PPS	C	C	A	C
PEEK	A	B	O	O
PPSU	A		C	C
UHMWPE	C	C	B	C

A = resistant
B = partially resistant
C = not resistant
O = soluble

Source: https://www.mcam.com/de/support/chemical-resistance-information (assessed 2023/09/20)

Elastic materials in mechanical and plant engineering

Problems with Mechanical Properties & Temperature

Mechanical Properties heavily depend on the Compound Composition!

Properties can have a broad range and the information can vary depending on the source

- Compound composition needed for detailed information
  - Not always given in datasheets or public information
- General data varies
  - E.g., no information about ACN content in NBR or HNBR given → influence on the mechanical properties!
  - E.g., different producers have different ranges for similar materials → manufacturing process can have an influence
- Temperature resistance depends on the chosen rubber
  - Can be shifted a little by the crosslinking or monomer composition → will influence the mechanical properties!

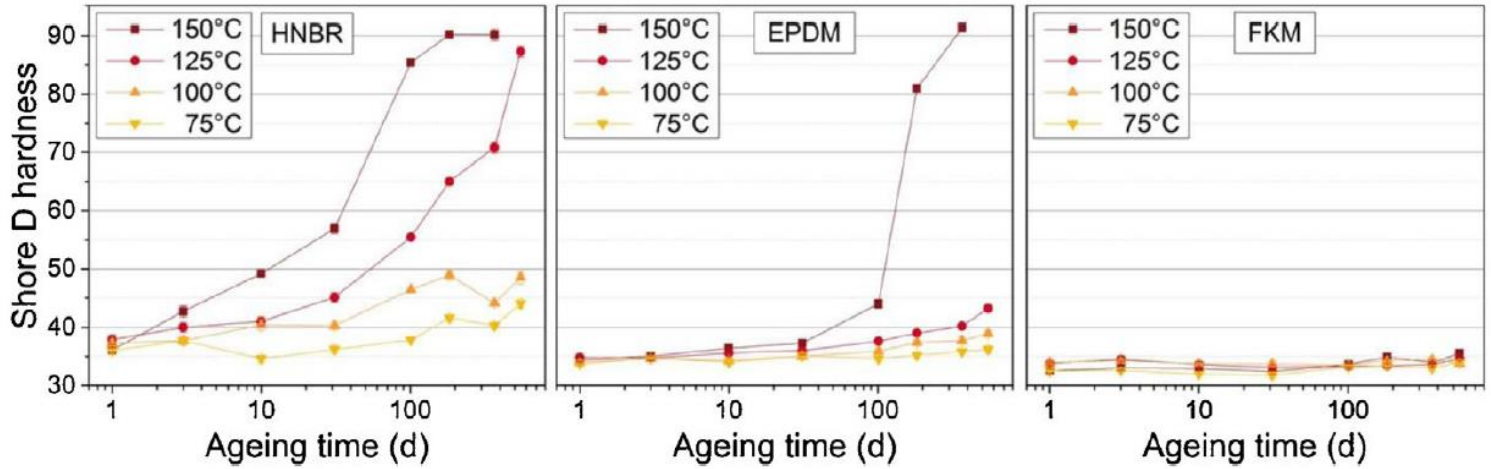
➢ You have to check out specific rubber materials in combination with specific fillers, additives and curing systems for a solution

Fluoroelastomers

Substitution Limits – Example: Aging behaviour

- PVDF-Elastomer: 200°C, **95% residual strain after 1 year**
- Nitril-Elastomer: 150°C, 50% residual strain after 10 days
- Acrylat-Elastomer: 150°C, 50% residual strain after 25 days

Shore D hardness of HNBR, EPDM and FKM vs. aging time



Macromol. Symp. 2017, 373, 1600157

Conclusion

The substitution of PFAS is sometimes possible but it is usually a case-by-case decision, depending on the specific application

- It is undisputed that some PFAS pose risks to health and the environment.
- The unique combination of chemical stability, thermal stability, tribology, durability and mechanical properties makes it difficult to substitute PFAS in industrial and medical applications.
- There are currently no substitute materials with this unique combination of materials.
- Whether or not substitute materials are available depends on whether this combination is essential for the application.
- Clustering by general application, such as mechanical engineering or medical technology, improves the search for substitute materials only slightly.

➢ Substitute materials must be evaluated separately for each specific requirement and application. The Database can assistance in making the preliminary choice.

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Thank you very much for your attention!

Contact Fraunhofer LBF

Dr. Christian Beinert
Phone. +49 6151 705-8735
Christian.beinert@lbf.fraunhofer.de