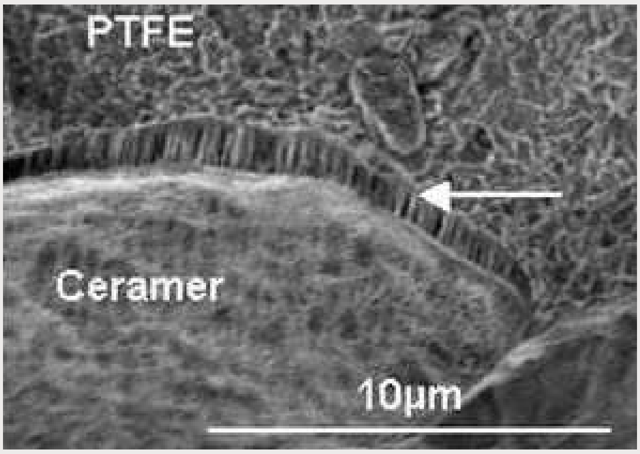
PTFE COMPOUNDS – COMPRESSION MOLDING

- **Ceramer** and **Ceramerplus** are ideal as reinforcing materials for PTFE and greatly improve the abrasion resistance and creep tendency.
- The particle shape, spherical with a rough, cracked surface, enables the material to form an intimate mechanical bond with matrix substances such as fluoropolymers.
- The general outstanding chemical and temperature resistance of PTFE are not affected as the properties of **Ceramer** and **Ceramerplus** are very similar to those of PTFE.
- Due to the low density of **Ceramer** (1.44 -1.54 g/cm^3), a large volume load can be achieved with little weight gain. Ceramer is typically used as additive in a range of 5 - 15 percent by weight.
- **Ceramer** and **Ceramerplus** can be processed under standard PTFE processing conditions such as compression molding powders or paste extrusion powders.



Scanning electron micrograph of compound of PTFE and Ceramer 20. Note the stable stretched fibrils at the interface revealing the excellent bonding

EXTENDED APPLICATIONS THROUGH CERAMER

- The enhancement of PTFE properties, by **Ceramer** are very beneficial in automotive applications and in chemical processing technologies. In applications such as seals bearings, gaskets and pump housings **Ceramer** contributes substantially with regard to tribological behavior and creep tendency without changing chemical resistance.
- Also in other markets such as: Oil and natural gas and food processing, PTFE / **Ceramer** bearings, seals and gaskets have offered superior performance. This is especially true in the case of parts facing high abrasion at high temperatures and in corrosive environments.
- With **Ceramerplus** a material is offered that further widens the range of applications, particularly for large sized or extremely stressed parts.

TRIBOLOGICAL PEAK VALUES ACHIEVED

Seal rings made from PTFE / Ceramer compounds are remarkable for their abrasion and wear resistance

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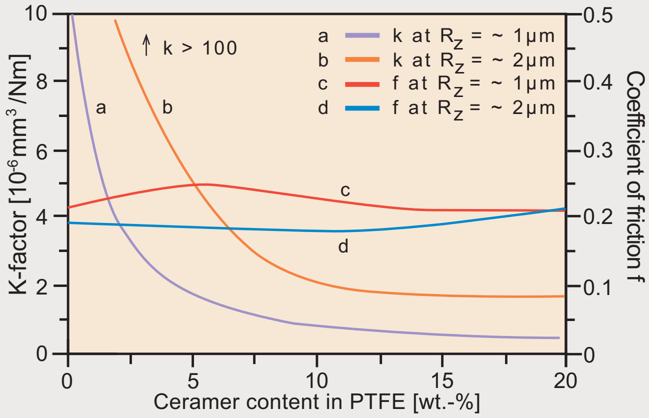
INFLUENCE OF CERAMER ON ABRASION AND WEAR

- Abrasion and wear of PTFE against metallic partners clearly show improved values even beginning at very low loading of **Ceramer** or **Ceramerplus** in PTFE. The coefficient of friction of PTFE (curve c and d) is hardly changed by the addition of **Ceramer** and **Ceramerplus.**

- The k-factor is a widely used term to describe abrasive properties. It is made up of abrasion in [mm/m] divided by the contact pressure in [N/mm^2]. The results (curve a and b) clearly demonstrate the significant reduction of the k-factor even at a low filler content.

Effect on k-factor and coefficient of friction



Conditions:
Pin-on-disc machine at various surface roughness Rz, p = 5 N/mm^2,
v= 0.5 m/s, T= 23 °C, technically dry.

Details on testing conditions

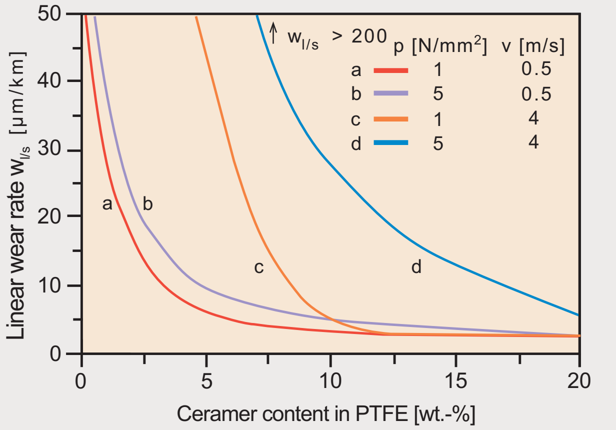
Measurements were carried out in air with a pin-on-disc test instrument, using hardened steel (100 Cr6, Rockwell hardness HRC >50) abrasive discs as abrasive partners. The surface roughness (Rz) of the abrasive discs was determined before each test. Only the stationary phase was used for evaluating the test data. In this phase the coefficient of friction is constant and there is uniform wear, i.e. wear increases linearly with time. Test data were determined on-line and the test duration was 20 hours, except in the case of pure PTFE, since these test specimens very quickly wore out. Here the tests lasted four hours.

- PTFE Compounds with **Ceramer** show improved properties at various sliding speeds and at high and low contact pressure.

- The figure on the right clearly shows the improvement of the wear properties of PTFE through the addition of **Ceramer** at high and low sliding speed.

- With 20% **Ceramer** addition, PTFE can also be used at high surface pressure (p = 5 N/mm^2) and equally at high sliding speeds (v = 4 m/s). Under low stress (v = 0.5 m/s; p = 1 N/mm^2) the addition of 10% **Ceramer** is sufficient.

Effect on linear wear rate w



Linear ware rate $w_{l/S}$ of PTFE / Ceramer compounds as a function of contact pressure p and the sliding speed v in the pin-on-disc machine. conditions: Rz ~ 1 µm; technically dry.

TRIBOLOGICAL PEAK VALUES

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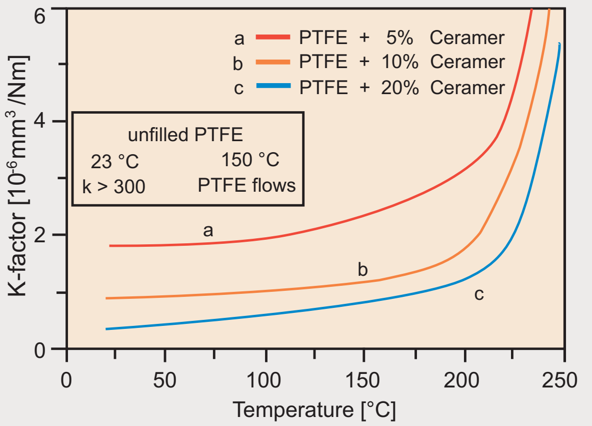
INFLUENCE OF CERAMER ON ABRASION AND WEAR

- The temperature resistance of PTFE/- **Ceramer** compounds was measured in tests with the sliding surface temperature above of 23 °C. At temperatures over 150 °C, unfilled PTFE flows under stress.
- Through the addition of small amounts of **Ceramer**, the temperature can be raised to over 200 °C.
- The maximum temperatures at which PTFE/**Ceramer** compounds can be used lies at between 220 °C and 260 °C, depending on the **Ceramer** content. In this temperature range, the **Ceramer** content should be at least 10% to 20%.

Effect on k-factor as function of temperature



K-factor of PTFE / Ceramer compounds as function of the sliding surface temperature in the pin-on-disc machine.
Conditions: Rz ~1 µm. p = 5 N/mm². v = 0.5 m/s. technically dry.

OUTSTANDING PERFORMANCE AT HIGH TEMPERATURES

INFLUENCE OF CERAMER ON ABRASION AND WEAR AT VARIOUS CONDITIONS

Measurement conditions				k-factor [10^{-6}mm³ /Nm]				Coefficient of friction			
Temperature [°C]	contact pressure [N/mm²]	sliding speed [m/s]	Surface roughness R_Z [µm]	PTFE filled with Ceramer Ceramer content [%]				PTFE filled with Ceramer Ceramer content [%]			
				0	5	10	20	0	5	10	20
23	1	4	1	168	43	4.6	1.9	0.31	0.30	0.29	0.28
23	5	4	1	354	104	5.3	1.1	0.30	0.22	0.26	0.28
23	1	0.5	1	319	5.2	2.8	2.1	0.20	0.28	0.20	0.29
23	5	0.5	1	494	1.8	1.0	0.4	0.22	0.25	0.23	0.21
23	5	0.5	2	72	5.2	2.2	1.8	0.19	0.19	0.18	0.21
150	1	0.5	1	43	2.3	1.2	0.6	0.30	0.43	0.39	0.35
200	1	0.5	1	*	3.2	1.1	1.3	*	0.21	0.15	0.13

*Material flows

See preview page

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INFLUENCE OF CERAMER ON THERMAL EXPANSION OF PTFE

- The coefficient of linear thermal expansion of pure PTFE varies considerably with temperature. This can cause problems with the dimensioning and practical use of components constantly exposed to changing temperatures.

- Increasing amounts of Ceramer as reinforcing material in PTFE not only reduces the dependence of the coefficient of the linear thermal expansion on temperature, but also lowers its absolute value. This makes it much easier to dimension components, whose shape will tend to change less with the changing ambient temperatures.

Coefficient of linear thermal expansion of PTFE and PTFE reinforced with Ceramer

Ceramer content in PTFE [%]	Coefficient of linear thermal expansion [10^{-6} K^{-1}]			
	10 - 30 °C	30 - 100 °C	100 - 170 °C	170 - 270 °C
0	231	107	126	172
5	220	100	110	150
10	194	83	99	123
20	189	76	86	111
50	80	57	63	88
75	46	46	50	60

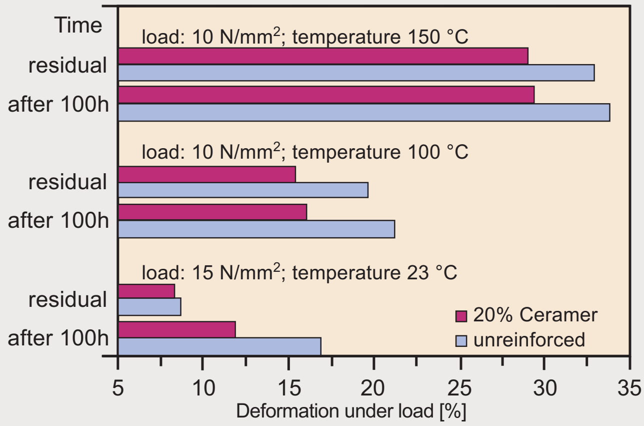
REDUCTION OF LINEAR THERMAL EXPANSION

INFLUENCE OF CERAMER ON THE CREEP BEHAVIOR OF PTFE

- The creep behavior of PTFE is one of its main weaknesses. Its tendency to creep is much reduced by incorporating Ceramer as an additive.

SIGNIFICANT REDUCTION OF CREEP

Deformation under load of pure and Ceramer filled PTFE



Test data refer to mixtures with Ceramer 20

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INFLUENCE OF CERAMER ON DENSITY AND MECHANICAL PROPERTIES

- The density of **Ceramer** is approximately 1.44 g/cm^3, of Ceramerplus approximately 1.54 g/cm^3. The low density makes cost effective material applications possible.

Compared to the fluoropolymers, whose density is >2 g/cm^3, the low density of the **Ceramer** and **Ceramerplus** enables a high volume load with little weight gain.

Density and mechanical properties of PTFE and PTFE reinforced with Ceramer

Ceramer content in PTFE [%]	Density [g/cm^3]	Tensile strength [N/mm^2]	Elongation at break [%]
0	2.17	29	380
5	2.08	17	470
10	1.96	18	400
20	1.90	13	300
Methods	ISO 1183	ASTM D 4894 & 4895	ASTM D 4894 & 4895

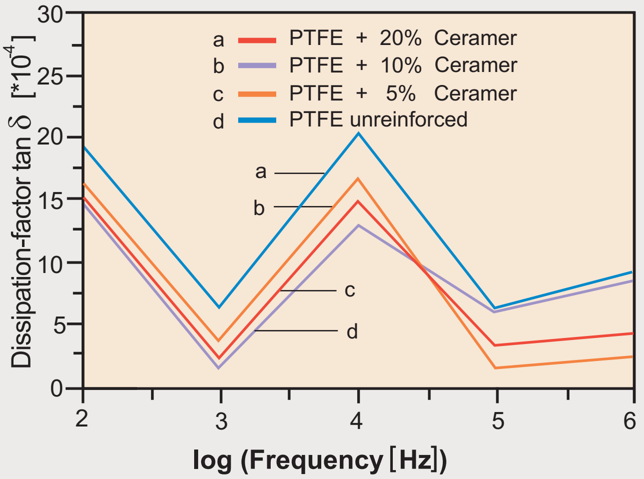
Test data refer to mixtures with Ceramer 20

LOW DENSITY OF CERAMER MAKES COST EFFECTIVE MATERIAL APPLICATIONS POSAIBLE

INFLUENCE OF CERAMER ON ELECTRICAL PROPERTIES

- The electrical properties are practically unaffected. The addition of **Ceramer** to PTFE has hardly any effect on the material's electrical properties. The outstanding electrical insulating properties of PTFE are therefore nearly unchanged.
- The volume resistivity for PTFE and PFA of >10^{15} Ω cm stay for the material's reinforced with 5%, 10% or 20% at values >10^{15} Ωcm. (Determined according to IEC 93 at 23 °C, 50% relative humidity, voltage: 100 V).
- The dielectric constant of PTFE compounds with **Ceramer** increases from 2.07 (pure PTFE) to 2.34 (20% **Ceramer** content) and is not affected by the frequency. The dissipation factor tan δ is shown in the figure.

Dissipation factor tan δ of PTFE and PTFE Ceramer compounds



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