Ferroperm Piezoceramics

Ceramic Properties And The Practical Interpretation Of Suppliers' Catalogue Data

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Ferroperm Piezoceramics

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Outline

- Specifications and standards
- Frequency constant
- Dynamic properties
- Ageing (shelf life) and depoling effects
- Influence of the electrode
- Tolerance

Specifications and standards

Standards
Materials (CENELEC)

Ferroperm Piezoceramics

Material Cross Reference Chart

	Pz21	Pz23	Pz24	Pz26	Pz27	Pz28
CENELEC EN 50324 -1	600	N/A	500	100	200	300
NAVY 1376A		N/A		1	2	3
INDUSTRIAL	3302HD	N/A	7A	4D	5A	8

	Pz29	Pz34	Pz35	Pz46	Pz52	Pz54
CENELEC EN 50324 -1	600	700	800		N/A	N/A
NAVY 1376A	6				N/A	N/A
INDUSTRIAL	5H	2	K81	K15	N/A	N/A

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Specifications

Ferroperm Piezoceramics

Soft PZT

Pz23

Type II Pz27

Pz29

Hard PZT

Pz24

Type I Pz26

Pz28

Relaxor based Piezo

Pz21

Pz59

ES91*

Lead Titanate

Pz34

Bismuth titanate

Pz46

Pz48

"Lead meta-Niobate"

Pz35

Pz31

NEW!

HIFU Materials

Pz52

Pz54

NEW!

Low acoustic Imp PZT

Pz36

Pz37

Pz39

IN DEVELOPMENT

Pz49

Ultra high temperature sensors

IN DEVELOPMENT

Pz24FG

High density toughened Piezoceramics

IN DEVELOPMENT

Pz61

Lead Free Piezoceramics

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Specifications

Ferroperm Piezoceramic Materials

Material Data for standard test specimens, Measured at 25 °C and 24 hours after poling.

	Symbol	Unit	Pz21	Pz23	Pz24	Pz26	Pz27	Pz28	Pz29	Pz34	Pz35	Pz36	Pz37*	Pz39*	Pz46	Pz52*	Pz54*
Electrical Properties																	
Relative dielectric constant (1 kHz)	K_{33}^T	1	3800	1500	400	1300	1800	1000	2900	210	220	610	850	1780	120	1900	2800
Diel. dissipation factor (1 kHz)	$\tan\delta$	1	18	13	2	3	17	4	19	14	6	3	17	19	4	3	3
Curie temperature	$T_c >$	°C	205	350	330	330	350	330	235	400	500	350	350	220	650	250	225
Recommended working range	$T <$	°C	130	250	230	230	230	230	150	150	200	250	250	130	550	200	180
Electromechanical Properties																	
Coupling factors	k_p	1	0.62	0.52	0.50	0.57	0.59	0.58	0.64	0.07		0,26	0,25	0,19	0.03	0,6	0,6
	k_t	1	0.47	0.45	0.52	0.47	0.47	0.47	0.52	0.40	0.34	0,52	50	0,53	0.20	0,53	0,48
	k_{31}	1	0.34	0.29	0.29	0.33	0.33	0.34	0.37	0.05					0.02		
	k_{33}	1	0.71	0.65	0.67	0.68	0.70	0.69	0.75	0.40					0.09		
Piezoelectric charge coefficients	$-d_{31}$	10^{-12} C/N	250	130	55	130	170	120	240	5					2		
	d_{33}	10^{-12} C/N	600	330	190	300	425	275	575	50	90	230	340	480	18	420	500
	d_{15}	10^{-12} C/N		420			500								16		
Piezoelectric voltage coefficients	$-g_{31}$	10^{-3} V·m/N	7	10	16	11	11	13	10	3					2		
	g_{33}	10^{-3} V·m/N	18	25	54	28	27	31	23	25	43	40	40	30	17	25	20
Frequency constants	N_p	Hz·m	2030	2160	2400	2230	2010	2180	1970	2770					2470	2090	2125
	N_t	Hz·m	1970	2030	2100	2040	1950	2010	1960	2200	1550	1270	1170	1190	2000	1960	1950
	N_{31}	Hz·m		1480	1670	1500	1400		1410								
	N_{33}	Hz·m		1600	1600	1800	1500		1500								
Mechanical Properties																	
Density	ρ	g/cm³	7.85	7.70	7.70	7.70	7.70	7.70	7.45	7.55	5.60	5,6	5,7	5,8	6.55	7,3	7,8
Mechanical quality factor	Q_m	1	65	100	>1000	>1000	80	>1000	90	>500	~15	500	50	70	>600	550	1000

* New materials. Full data matrix will be published as soon as possible.

Standards
Materials (CENELEC)

Ferroperm Piezoceramics

Table1. Classes of Materials, CENELEC (European) standards.

			Type 100 Hard PZT		Type 200 Soft PZT		Type 300 Very hard PZT		Type 400 Barium Titanate	
Property	Symbol	Unit	Min	Max	Min	Max	Min	Max	Min	Max
Free relative permittivity	ε^T_{33}		1100	1600	1600	2500	800	1150	700	1400
Dielectric loss factor	$\tan \delta_d$	10^{-3}		6		25		5		10
Increase in ε^T_{33} from 0-400 V/mm		%		20						
Increase in tan δ_d from 0-400 V/mm		%		1000				300		
Planar piezoelectric coupling factor	k_p		0.55		0.55		0.50		0.23	
Curie Temperature	T_C	°C	300		330		300		100	
Mechanical quality factor	Q_m		300			100	800		400	
Piezoelectric charge coefficients	d_{33}	10^{-12} C/N	250		400		200		100	

			Type 500 Hard PZT Low ε^T_{33}		Type 600 Very soft PZT		Type 700 Lead Titanate		Type 800 Lead Meta-niobate	
Property	Symbol	Unit	Min	Max	Min	Max	Min	Max	Min	Max
Free relative permittivity	ε^T_{33}		300	850	2500		150	300	200	300
Dielectric loss factor	$\tan \delta_d$	10^{-3}		5		30		30		10
Increase in ε^T_{33} from 0-400 V/mm		%								
Increase in tan δ_d from 0-400 V/mm		%								
Planar piezoelectric coupling factor	k_p		0.40		0.55			0.10*		0.10*
Curie Temperature	T_C	°C	250		180		230		400	
Mechanical quality factor	Q_m		800			100	500			20
Piezoelectric charge coefficients	d_{33}	10^{-12} C/N	150		500		40		70	

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Standards

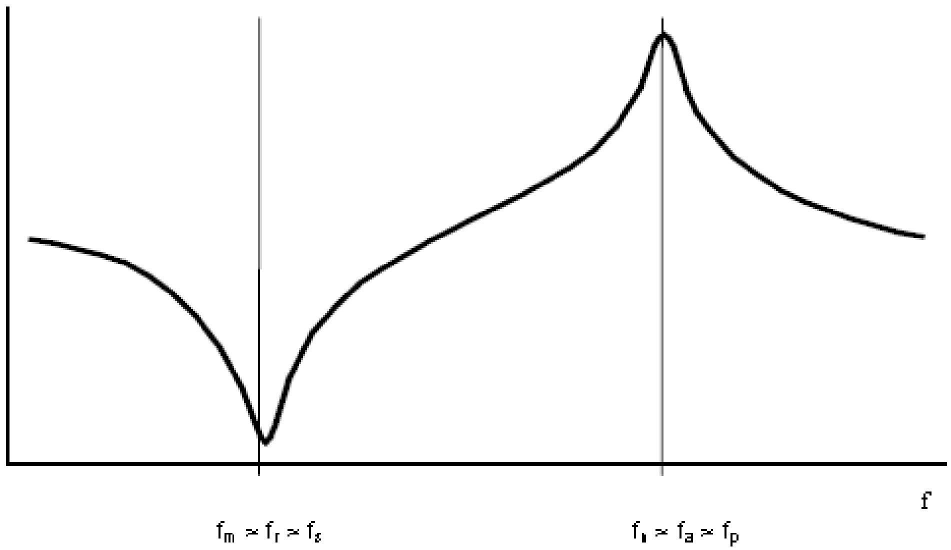


Figure 2 - Measured impedance of a piezoceramic transducer

$$k_{eff}{}^2 = \frac{f_p^2 - f_s^2}{f_p^2}$$

Standards
Measurements (CENELEC)

Ferroperm Piezoceramics

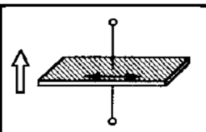
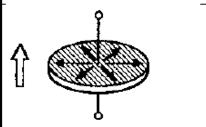
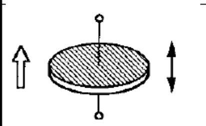
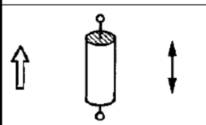
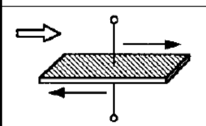
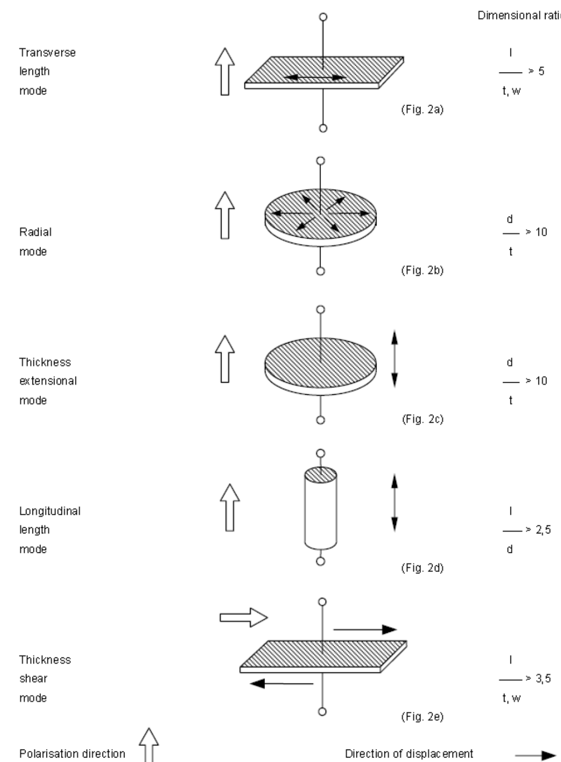
Transverse length mode		C^T	53	ε_{33}^T				
		f_r, f_a	16	s_{11}^E	21	s_{11}^D		
			37	k_{31}	45	d_{31}	46	g_{31}
Radial mode		C^T	53	ε_{33}^T	55	ε_{33}^S		
		f_r, f_a	38,41	k_p	26	σ^E	25	s_{12}^E
Thickness extension mode		f_m						
		f_r, f_a	42	k_t	55	ε_{33}^S		
			19	c_{33}^D	24	c_{33}^E	28	s_{13}^E
Longitudinal length mode		f_r, f_a	43	k_{33}	47	d_{33}	48	g_{33}
			17	s_{33}^D	22	s_{33}^E		
		C^T	53	ε_{33}^T				
Thickness shear mode		f_r, f_m	44	k_{15}	49	d_{15}	50	g_{15}
			18	s_{55}^D	23	s_{55}^E	20	c_{55}^D
		C^T	54	ε_{11}^T	56	ε_{11}^S	20	c_{55}^E

Figure 8 - Step-by-step procedure for calculating a complete set of material coefficients of piezoceramics

EN 50324-1:2002 – 14 –



(l = length, w = width, t = thickness, d = diameter)

Figure 2 - Fundamental vibration modes of piezoceramic resonators

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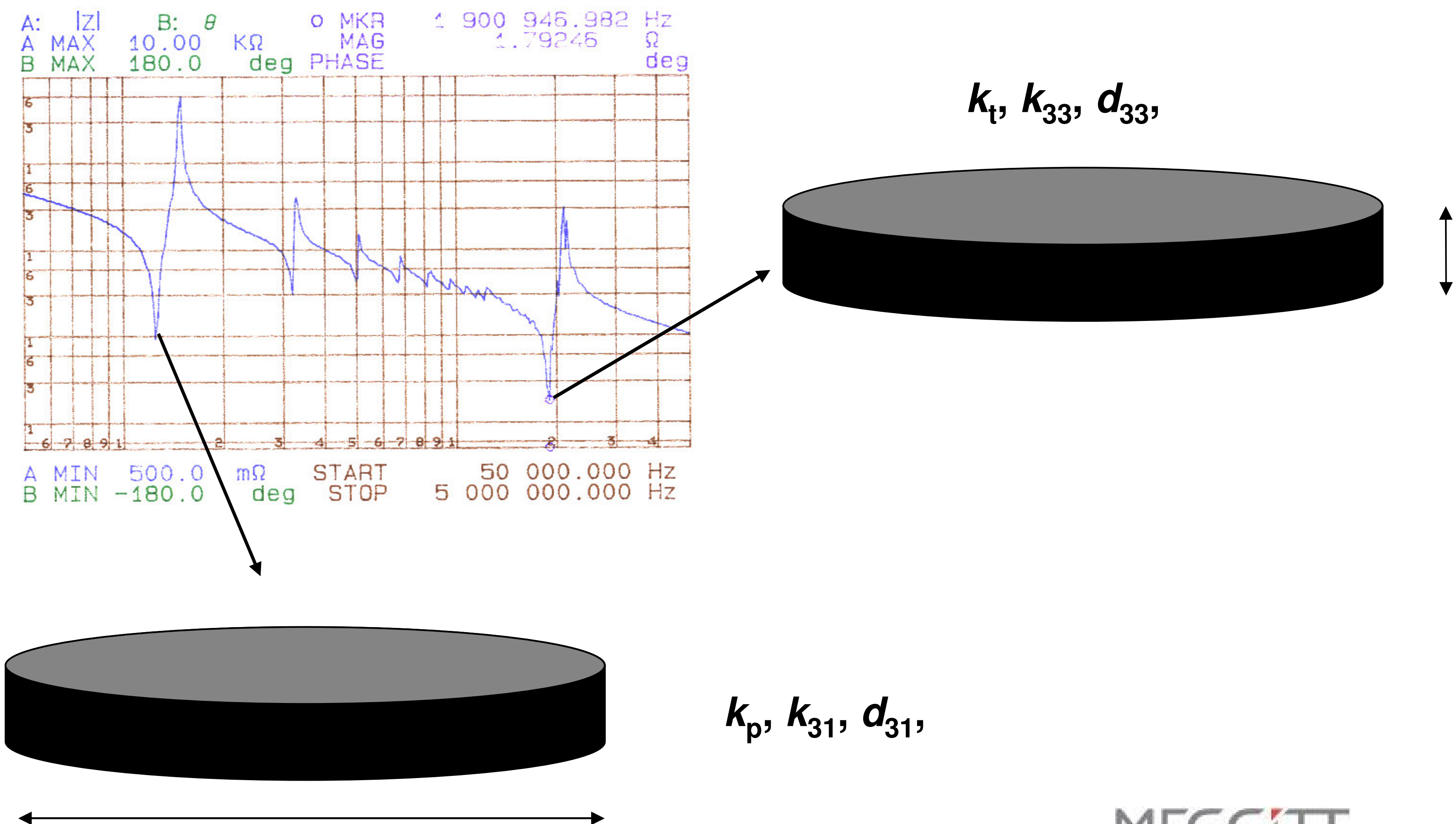
Frequency constant

Impedance spectrum

Impedance spectrum of a disc



Impedance spectrum soft and hard PZT

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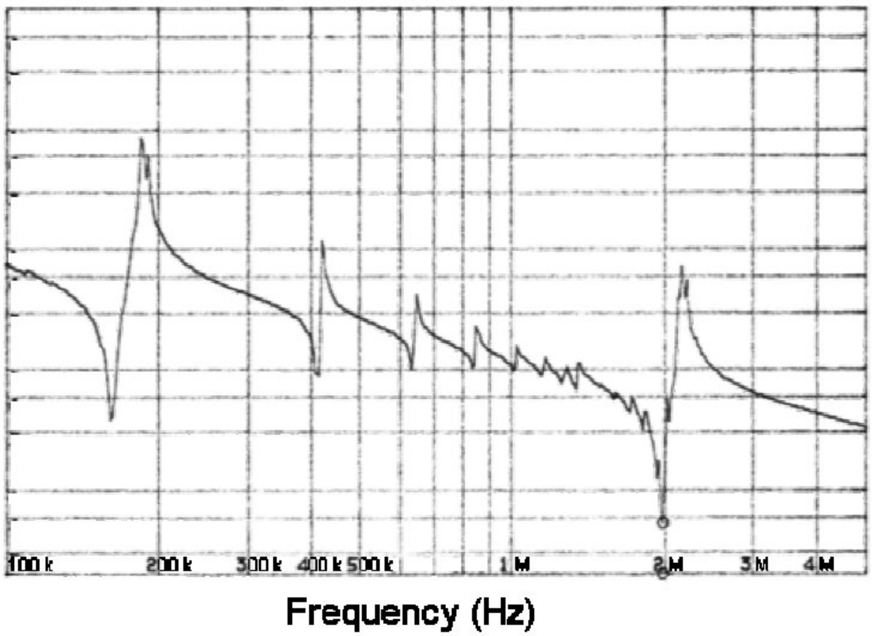

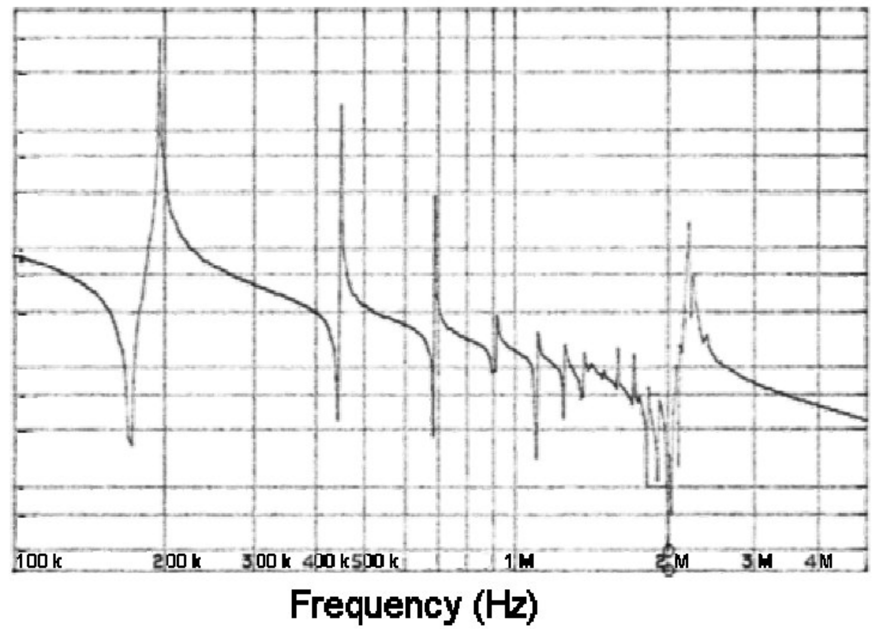

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Impedance spectrum shape

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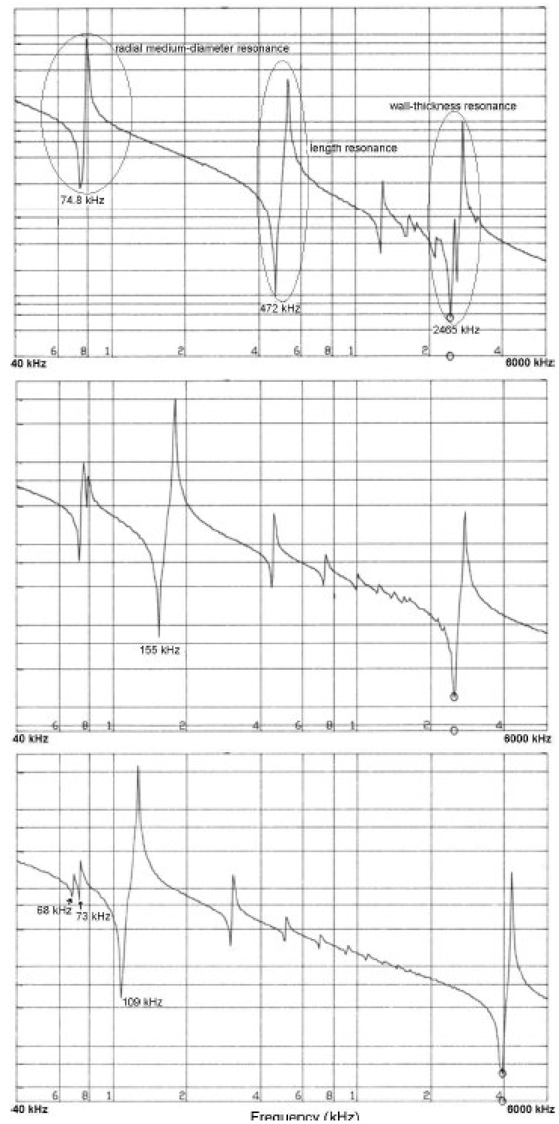

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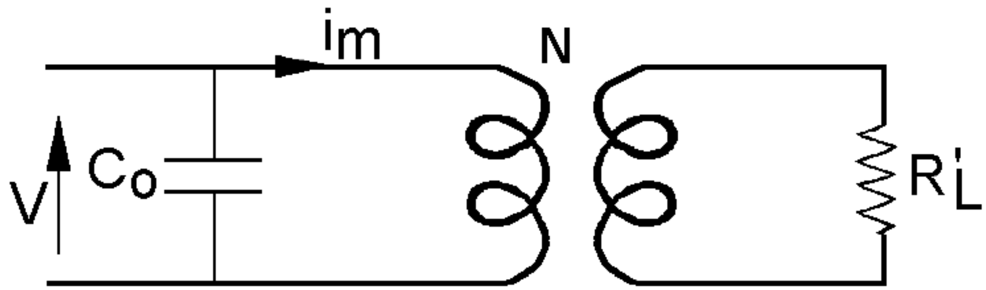
Dynamic properties

Dynamic



A = electrode area

ℓ = length for longitudinal and transverse length modes, thickness t for thickness extensional and thickness shear modes

R'_L = mechanical or acoustical load resistance

C_o = clamped capacitance of the sample

i_m = motional current

V = applied voltage

N = electromechanical transformer ratio

Dynamic

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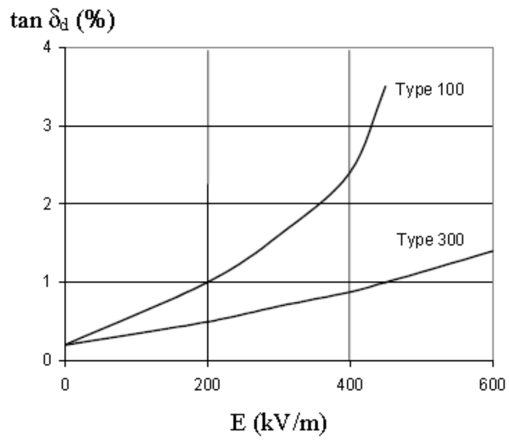

Figure 3 - Loss tangent versus electric field (1 kHz)

Table 2 - Large signal dielectric properties of groups 100 and 300 ceramic standard type (measured in air at 1 kHz)

Property		Type 100		Type 300
Applied electric field kV/m (rms)	E	200	400	400
Max. change in ε_{33}^T (percent) above small signal value (0,1 V/mm to 1,0 V/mm)	$\Delta\varepsilon_{33}^T/\varepsilon_{33}^T$	5	18	4,0
Max. dielectric loss factor	$\tan\delta_d$	0,02	0,04	0,01

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Dynamic

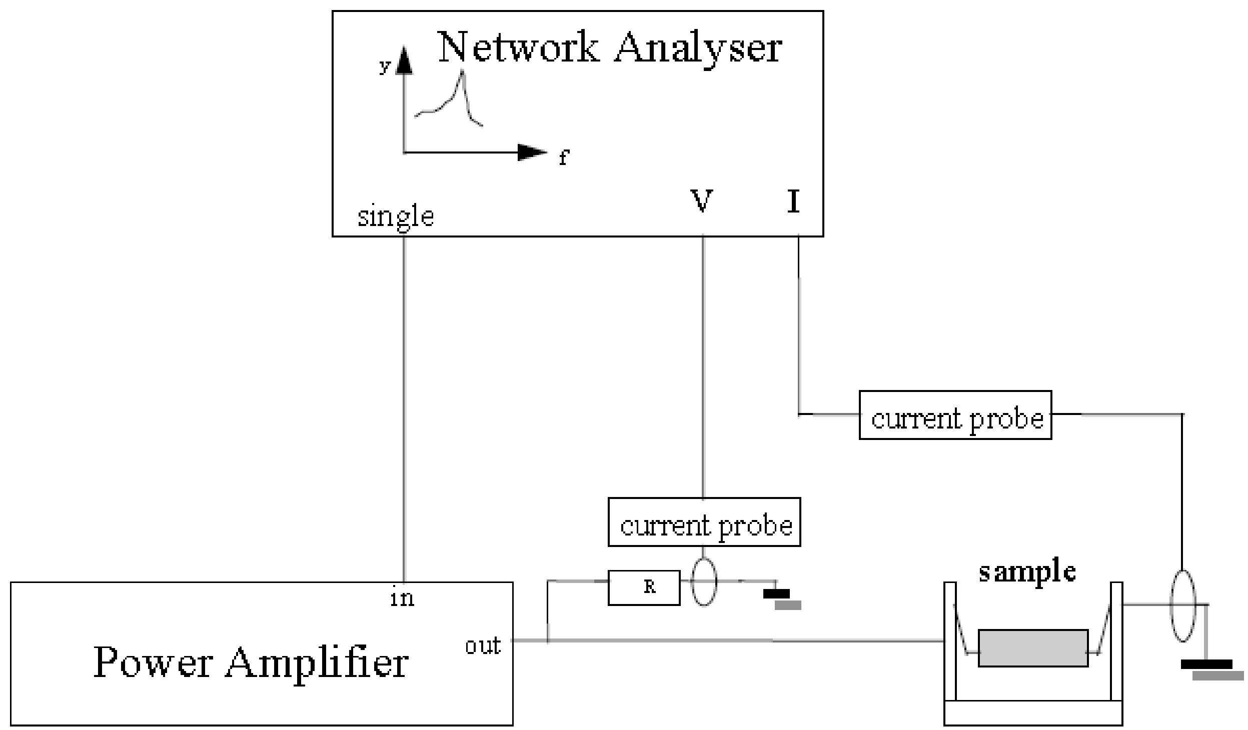

Figure 4 - Experimental set-up for mechanical losses measurement

Ageing (shelf life) and depoling effects

Ageing

- Ageing is logarithmic if the ceramic is driven a room temperature at low power
- When temperature, field and stress increases the aging is accelerated
- If combined the factors can amplify each other

Influence of the electrode

Influence of the electrode

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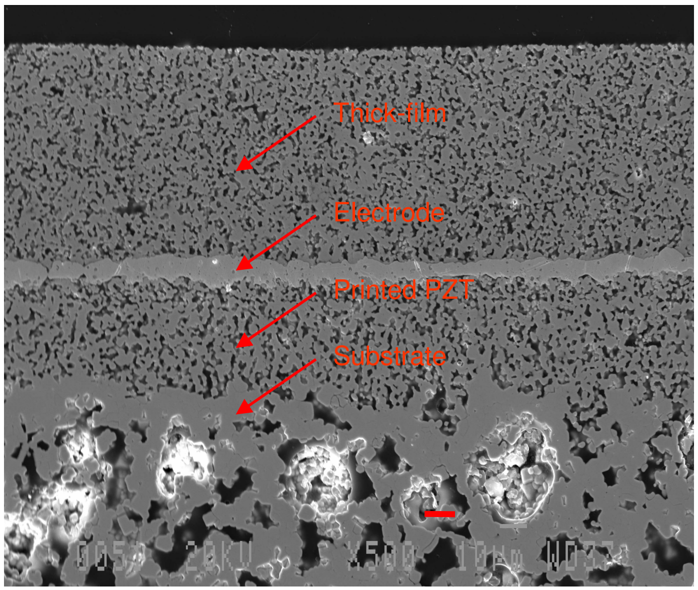
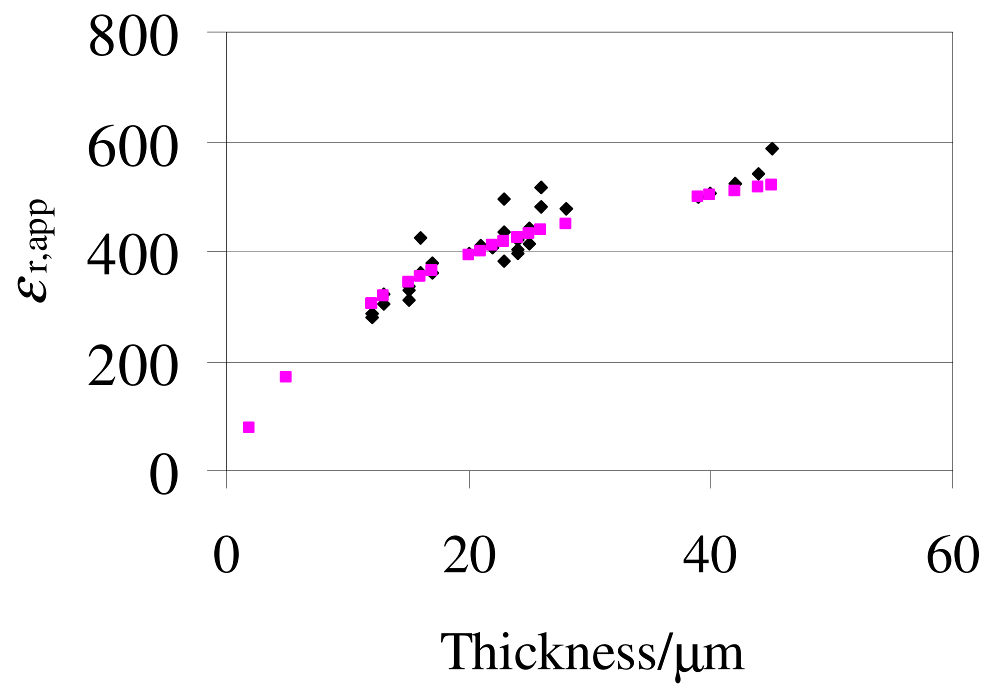
Thick film





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Influence of the electrode

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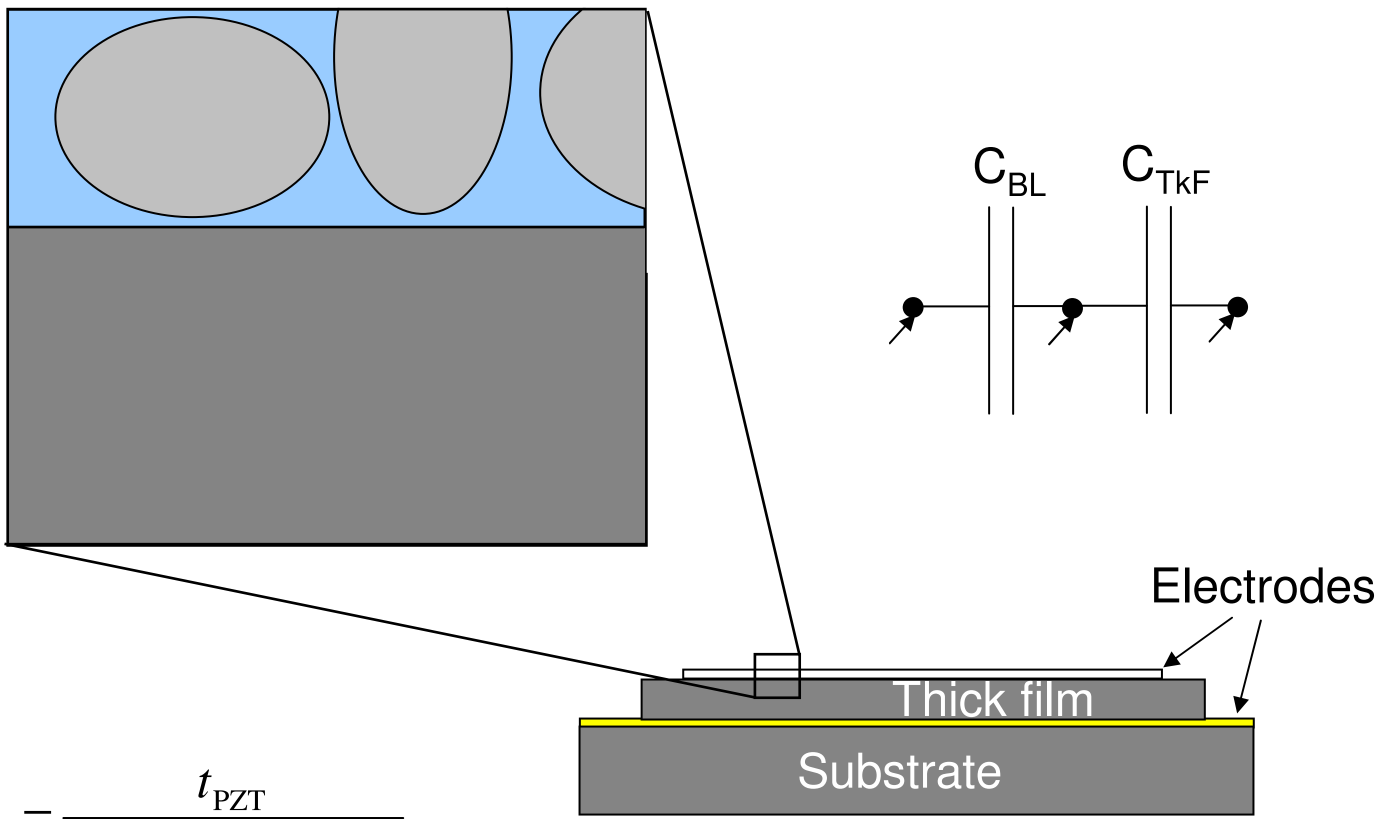

$$\varepsilon_{\mathrm{r,app}} = \frac{t_{\mathrm{PZT}}}{t_{\mathrm{PZT}}/\varepsilon_{\mathrm{PZT}} + t_{\mathrm{frit}}/\varepsilon_{\mathrm{frit}}}$$

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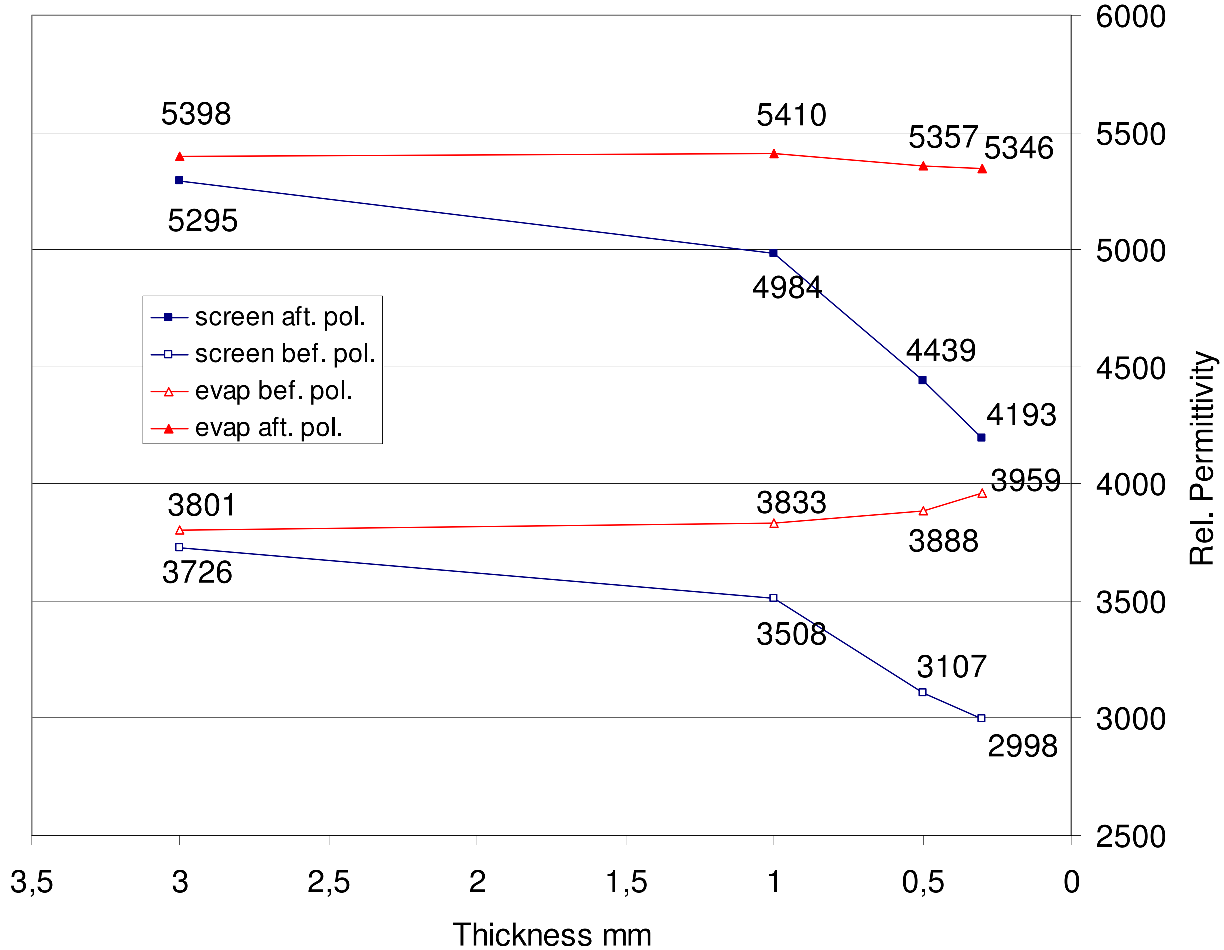
Influence of the electrode

Ferroperm Piezoceramics



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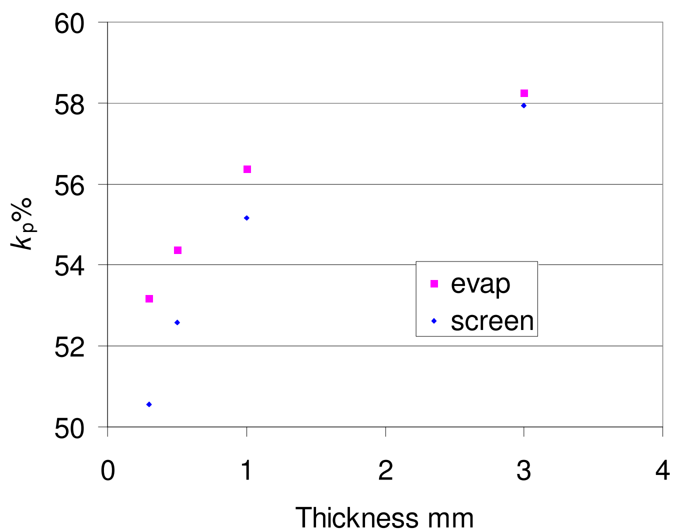
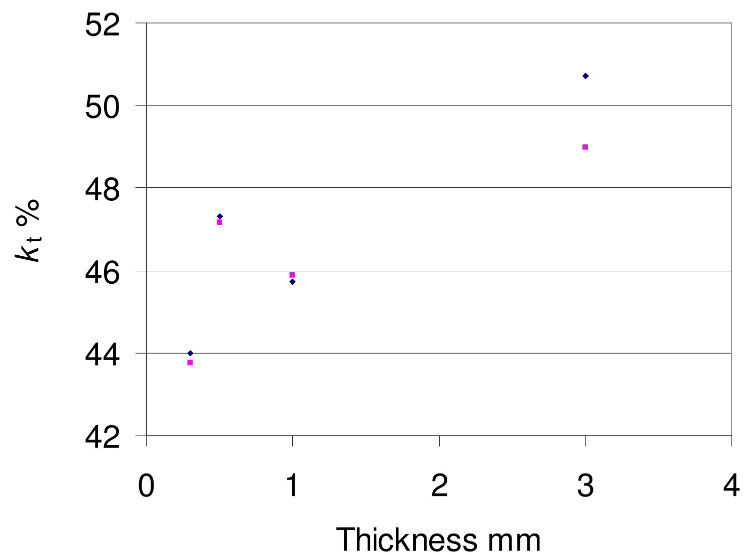
Influence of the electrode

Ferroperm Piezoceramics





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Summary

- When choosing a material for a transducer design one should know how to interpret material data sheet
- Properties are measured using standards which are specified in terms of measurement setup and sample geometry
- Real conditions may differ from the ideal case
- Extreme driving conditions can affect the performance
- The electrodes affect the apparent properties of the ceramic componenet