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ELECTRONIC HARDWARE AG

MEASUREMENT SPECIALTIES

Piezo Film Sensors

Technical Manual

Internet Version

Part 7 of 18

Pyroelectric Basics
Table 5. Comparison of Pyroelectric Materials

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PYROELECTRIC BASICS

Piezoelectric polymers, such as PVDF and its copolymers of VF_2/VF_3, are also pyroelectric. Pyroelectric sensor materials are normally dielectric materials with a temperature-dependent dipole moment. As these materials absorb thermal energy, they expand or contract, thereby inducing secondary piezoelectric signals. As piezo film is heated, the dipoles within the film exhibit random motion by thermal agitation. This causes a reduction in the average polarization of the film, generating a charge build up on the film surfaces. The output current is proportional to the rate of temperature change (ΔT). The amount of electrical charge produced per degree of temperature increase (or decrease) is described by the pyroelectric charge coefficient, ρ.

The charge and voltage produced in a given film of area A permittivity ε, and thickness t is given by:

$$Q = p\Delta TA$$

$$V = p\ \Delta T/\varepsilon$$

EXAMPLE 5:

A piezo film pyroelectric detector having a film thickness (t) of 9µm, a permittivity (ε) of 106×10^{-12} C/Vm and a pyroelectric coefficient (p) of 30×10^{-6} C/($m^{2\circ}$K), undergoes a temperature increase (ΔT) of 1°K due to incident IR radiation. The output voltage is given by:

$$V = \frac{(30x10^{-6}\,C/m^{2}\,{}^{\circ}K)(9x10^{-6}\,m)(1\,{}^{\circ}K)}{(106x10^{-12}\,C/Vm)}$$

$$V = 2.5 \text{ volts}$$

The pyroelectric voltage coefficient of piezo film is about an order of magnitude larger than those of Lead Zirconate Titanate (PZT) and Barium Titanate ($BaTiO_3$). Table 5 compares the pyroelectric properties of these materials.

Table 5. Comparison of pyroelectric materials

Material	TGS	$LiTaO_3$	$BaTiO_3$	PZT	$PbTiO_3$	PVDF	VF_2VF_3
ρ_Q	350	200	400	420	230	30	50
$\varepsilon/\varepsilon_o$	30	45	1000	1600	200	10.7	8.0
α	.16	1.31	1.00	.44	.67	.06	.06
L	225	646	564	374	461	138	138
P_v	1.32	.50	.05	.03	.10	.47	.71
M_l	.53	.16	.02	.01	.03	.20	.31
Pyroelectric Charge Coefficient				(ρ_Q)µCoul/[m^2• °K]			
Dielectric Constant				($\varepsilon/\varepsilon_o$),where ε_o=8.85pF/m			
Thermal Diffusivity				(α)m^2/sec •10^{-6}			
Thermal Diffusion Depth @ 1Hz				(L)µm			
Pyroelectric Voltage Coefficient				(P_V)ρ_Q/ε, V/[µm• °K]			
Figure of Merit				(M_l)ρ_Q/[C_V •ε], V •mm^2/J			

Piezo film advantages including:
— moisture insensitivity (<.02% H_2O absorption)
— low thermal conductivity
— low dielectric constant
— chemical inertness
— large detector sizes

The pyroelectric response of piezo film can also become a noise source for piezo sensor applications at low frequencies. In piezoelectric applications where low frequency strain sensing is desired, there are several convenient methods to “common-mode reject” the pyroelectric response. Examples include:

- Two equal sized electrode patterns on one piezo film element; one electrode oriented parallel to the d_{31} and the other electrode pattern is perpendicular to the d_{31} direction. Both develop equal signals in response to pyro, but the electrode area parallel to the d_{31} develops about 10X the perpendicular electrode pattern. Subtracting the signals yields a pure piezo response.
- Two equal sized piezo film elements, laminated in a stacking configuration; one film has d_{31} parallel to strain surface, the other has d_{31} perpendicular to strain surface. As above, signals are subtracted to isolate the piezo response from pyro.
- Several other common mode rejection techniques can be described by MSI’s applications engineers.

For higher frequencies, where the rate of temperature change seen by the piezo film element is slower than the strain event to be measured, frequency filters readily sort out the unwanted pyro signal.