

GaPO₄

Material Constants

GaPO₄ (gallium phosphate) is a high temperature piezoelectric crystal, with superior sensing properties without any pyroelectric characteristics. This crystal has been used in technical applications such as pressure sensors since 1994.

GENERAL DATA

Point group	32 (D ₃) (quartz-homeotype)
Lattice constants (25°C)	a = 4.901 Å, c = 11.048 Å
Density (25°C)	3570 kg/m ³

PIEZOELECTRIC CONSTANTS

	25°C	500°C	700°C	950°C
d ₁₁ ^{a,b} [pC/N]	4.5	4.5	4.5	4.1 ^c
d ₁₄ ^a [pC/N]	1.9	1.6	1.4 ^c	1.0 ^c

$$d = \begin{pmatrix} d_{11} & -d_{11} & 0 & d_{14} & 0 & 0 \\ 0 & 0 & 0 & 0 & -d_{14} & -2d_{11} \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

THERMAL EXPANSION COEFFICIENTS

at T₀ = 25°C, -253°C < T < 900°C

	α _{ii} (T ₀) [10 ⁻⁶ K ⁻¹]	Tα _{ii} ⁽¹⁾ [10 ⁻⁹ K ⁻²]	T ² α _{ii} ⁽²⁾ [10 ⁻¹² K ⁻³]	T ³ α _{ii} ⁽³⁾ [10 ⁻¹⁵ K ⁻⁴]
α ₁₁	12.78	10.6	-16.1	12.3
α ₃₃	3.69	5.0	-5.4	3.6

$$\alpha = \begin{pmatrix} \alpha_{11} & 0 & 0 \\ 0 & \alpha_{11} & 0 \\ 0 & 0 & \alpha_{33} \end{pmatrix}$$

$$\alpha_{ii}(T) = \alpha_{ii}(T_0) + \sum_{n=1}^3 [\Gamma \alpha_{ii}^{(n)} \cdot (T - T_0)^n]$$

THERMAL CONDUCTIVITY

	50°C	70°C	100°C	130°C	150°C	180°C	200°C
λ ₁₁ [W m ⁻¹ K ⁻¹]	4.21	3.96	3.68	3.28	3.07	2.85	2.71
λ ₃₃ [W m ⁻¹ K ⁻¹]	6.66	6.14	5.66	5.00	4.78	4.27	4.02

$$\lambda = \begin{pmatrix} \lambda_{11} & 0 & 0 \\ 0 & \lambda_{11} & 0 \\ 0 & 0 & \lambda_{33} \end{pmatrix}$$

ELECTRIC RESISTIVITY

	25°C	200°C	300°C	500°C	700°C	900°C
$\rho[\Omega\text{m}]$	$> 10^{15}$	$> 10^{13}$	$> 10^{11}$	$> 10^9$	$> 10^7$	$> 10^5$

ELASTIC CONSTANTS at $T_0 = 25^\circ\text{C}$, $-50^\circ\text{C} < T < 700^\circ\text{C}$

	c_{ij} [GPa]	$Tc_{ij}^{(1)}$ [10^{-6}K^{-1}]	$Tc_{ij}^{(2)}$ [10^{-9}K^{-2}]	$Tc_{ij}^{(3)}$ [10^{-12}K^{-3}]
c_{11}^E	66.58	- 44.1	- 28.5	- 59.4
c_{12}^E	21.81	- 226.7	- 70.8	- 205.7
c_{13}^E	24.87	- 57.6	41.3	- 109.9
c_{14}^{Eb}	3.91	507.2	280.6	- 99.9
c_{33}^E	102.13	- 127.5	- 18.3	- 134.8
c_{44}^E	37.66	- 0.4	- 43.8	- 37.1
c_{66}^E	22.38	44.9	- 7.9	11.9

$$c = \begin{pmatrix} c_{11} & c_{12} & c_{13} & c_{14} & 0 & 0 \\ c_{12} & c_{11} & c_{13} & -c_{14} & 0 & 0 \\ c_{13} & c_{13} & c_{33} & 0 & 0 & 0 \\ c_{14} & -c_{14} & 0 & c_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & c_{44} & c_{14} \\ 0 & 0 & 0 & 0 & c_{14} & \frac{(c_{11} - c_{12})}{2} \end{pmatrix}$$

$$c_{ij}(T) = c_{ij}(T_0) \left[1 + \sum_{n=1}^3 Tc_{ij}^{(n)} \cdot (T - T_0)^n \right]$$

	s_{ij} [$10^{-12} \text{m}^2 \text{N}^{-1}$]	$Ts_{ij}^{(1)}$ [10^{-6}K^{-1}]	$Ts_{ij}^{(2)}$ [10^{-9}K^{-2}]	$Ts_{ij}^{(3)}$ [10^{-12}K^{-3}]
s_{11}^E	17.93	22.4	30.5	62.4
s_{12}^E	- 4.82	- 210.5	- 0.1	- 271.3
s_{13}^E	- 3.19	181.6	78.2	322.2
s_{14}^{Eb}	- 2.36	482.2	315.5	7.9
s_{33}^E	11.35	147.9	14.1	261.5
s_{44}^E	27.04	18.7	54.7	52.0
s_{66}^E	45.51	- 26.9	24.0	- 8.3

$$s = \begin{pmatrix} s_{11} & s_{12} & s_{13} & s_{14} & 0 & 0 \\ s_{12} & s_{11} & s_{13} & -s_{14} & 0 & 0 \\ s_{13} & s_{13} & s_{33} & 0 & 0 & 0 \\ s_{14} & -s_{14} & 0 & s_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{44} & 2s_{14} \\ 0 & 0 & 0 & 0 & 2s_{14} & 2(s_{11} - s_{12}) \end{pmatrix}$$

$$s_{ij}(T) = s_{ij}(T_0) \left[1 + \sum_{n=1}^3 Ts_{ij}^{(n)} \cdot (T - T_0)^n \right]$$

RELATIVE DIELECTRIC CONSTANTS

at $T_0 = 25^\circ\text{C}$, 1 kHz

	ϵ_{11}^T	ϵ_{11}^S	
	6.1		5.8
	ϵ_{33}^T	ϵ_{33}^S	6.6

$$\epsilon = \begin{pmatrix} \epsilon_{11} & 0 & 0 \\ 0 & \epsilon_{11} & 0 \\ 0 & 0 & \epsilon_{33} \end{pmatrix}$$

^a signs according to standard IEEE 176-1987 for right-handed crystals; for left-handed GaPO_4 crystals the signs of d_{11} , and d_{14} are changed

^b signs are changed according to IEC 60758 2004-12

^c predicted value

^T constant stress, ^S constant strain, ^E constant electric field