

INRAD Lithium Niobate

Lithium Niobate (LiNbO_3)

PHYSICAL PROPERTIES

Chemical Formula	LiNbO_3 congruently melting ¹	
Crystal Symmetry and Class	trigonal, $R3c$	
Point Group	3m	
Lattice Constants ² a = 5.15052(6) Å c = 13.86496(3) Å		
Density ²	4.648(5) g/cm ³	
Moh's Hardness	5	
Fracture Toughness ³	c-face x-face y-face	0.67 MPam ^{1/2} 1.07 MPam ^{1/2} 1.17 MPam ^{1/2}
Elastic Compliance ⁴ at Constant Polarization (S_P) and at Constant Field (S_E) and Temperature Dependence ⁵		
(TPa) ⁻¹	(TPa) ⁻¹	(10 ⁻⁴ /°K)
$S_{P11} = 4.76$	$S_{E11} = 5.78$	$(1/S_{E11})dS_{E11}/dT = 1.66$
$S_{P12} = -0.50$	$S_{E12} = -1.01$	$(1/S_{E12})dS_{E12}/dT = 0.28$
$S_{P13} = -1.20$	$S_{E13} = -1.47$	$(1/S_{E13})dS_{E13}/dT = 1.94$
$S_{P14} = 1.02$	$S_{E14} = -1.02$	$(1/S_{E14})dS_{E14}/dT = 1.33$
$S_{P33} = 4.19$	$S_{E33} = 5.02$	$(1/S_{E22})dS_{E22}/dT = 1.60$
$S_{P44} = 9.3$	$S_{E44} = 17.0$	$(1/S_{E44})dS_{E44}/dT = 2.05$
$S_{P66} = 10.5$	$S_{E66} = 13.6$	$(1/S_{E66})dS_{E66}/dT = 1.43$
Stiffness ⁴ at Constant Polarization (C_P) and at Constant Field (C_E) and Temperature Dependence ⁵		
(GPa)	(GPa)	(10 ⁻⁴ /°K)
$C_{P11} = 219$	$C_{E11} = 203$	$(1/C_{E11})dC_{E11}/dT = -1.74$
$C_{P12} = 37$	$C_{E12} = 53$	$(1/C_{E12})dC_{E12}/dT = -2.52$
$C_{P13} = 76$	$C_{E13} = 75$	$(1/C_{E13})dC_{E13}/dT = -1.59$
$C_{P14} = -15$	$C_{E14} = 9$	$(1/C_{E14})dC_{E14}/dT = -2.14$
$C_{P22} = 252$	$C_{E22} = 245$	$(1/C_{E22})dC_{E22}/dT = -1.53$
$C_{P44} = 95$	$C_{E44} = 60$	$(1/C_{E44})dC_{E44}/dT = -2.04$
$C_{P66} = 91$	$C_{E66} = 75$	$(1/C_{E66})dC_{E66}/dT = -1.43$

OPTICAL AND ELECTRO-OPTICAL PROPERTIES

Optical Symmetry uniaxial negative

Optical Transmission 0.400 μm - 5.0 μm

Sellmeier Equation Constants¹³

$$n = (A + B/(\lambda^2 + C) + D\lambda^2)^{1/2} ; \quad \lambda \text{ in microns}$$

n_o A=4.9048	B=0.11768	C= -0.0475	D= -0.027169
n_e A=4.582	B=0.099169	C=-0.044432	D= -0.02195

Calculated Refractive Index Values¹³

$n_o(1.064 \mu\text{m}) = 2.2322$;	$n_e(1.064 \mu\text{m}) = 2.1560$
$n_o(2.060 \mu\text{m}) = 2.1949$;	$n_e(2.060 \mu\text{m}) = 2.1243$
$n_o(3.500 \mu\text{m}) = 2.1405$;	$n_e(3.500 \mu\text{m}) = 2.0788$

Photoelastic Strain Coefficients at Constant Field¹¹

$\rho_{11} = -0.026$	$\rho_{31} = 0.17$
$\rho_{12} = 0.08$	$\rho_{33} = 0.07$
$\rho_{13} = 0.13$	$\rho_{41} = -0.151$
$\rho_{14} = -0.08$	$\rho_{44} = 0.146$

Temperature Variation of Refractive Index¹³ for $\lambda = 1.0 \mu\text{m} - 4.0 \mu\text{m}$

$$\begin{aligned} dn_o/dT &= 3.3 \times 10^{-6} / ^\circ\text{C} \\ dn_e/dT &= 37 \times 10^{-6} / ^\circ\text{C} \end{aligned}$$

Nonlinear d Coefficients^{12,20}

$$\begin{aligned} d_{22} &= 2.4 \text{ pm/V} \\ d_{31} &= -4.52 \text{ pm/V} \\ d_{33} &= 31.5 \text{ pm/V} \end{aligned}$$

Effective Nonlinear Optical Coefficient

$$d_{\text{eff}} = d_{31} \sin\theta - d_{22} \cos\theta \sin 3\Phi$$

Electro Optic Coefficients @ 0.633 μm ²³

$r_{13}^T = 10 \text{ pm/V}$	$r_{13}^S = 8.6 \text{ pm/V}$
$r_{22}^T = 6.8 \text{ pm/V}$	$r_{22}^S = 3.4 \text{ pm/V}$
$r_{33}^T = 32.2 \text{ pm/V}$	$r_{33}^S = 30.8 \text{ pm/V}$
$r_{51}^T = 32 \text{ pm/V}$	$r_{51}^S = 28 \text{ pm/V}$

Variation of Electro Optic Coefficient r_{22} with Wavelength²²
And Calculated Half-wave Voltage For 9mmx9mmx25mm Q-Switch

$$V_{1/4} = \lambda d / (4 n^3 r_{22})$$

r_{22}^T	$V_{1/4}$
1.064 $\mu\text{m} = 5.6 \text{ pm/V}$	1.55 kVolts
1.318 $\mu\text{m} = 5.4 \text{ pm/V}$	2.02 kVolts
1.55 $\mu\text{m} = 5.3 \text{ pm/V}$	2.44 kVolts
2.10 $\mu\text{m} = 5.2 \text{ pm/V}$	3.45 kVolts
2.79 $\mu\text{m} = 5.1 \text{ pm/V}$	4.78 kVolts
2.94 $\mu\text{m} = 5.1 \text{ pm/V}$	5.08 kVolts

Damage Threshold²

3 J/cm² @ 10 nsec

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THERMAL AND ELECTRICAL PROPERTIES

Melting Point⁷ 1240° C

Curie Temperature⁸ 1145° C

Thermal Conductivity⁹ 4. W/m°K

Thermal diffusivity⁶ $9 \times 10^{-7} \text{ m}^2/\text{sec}$

Specific Heat⁹ 0.633 J/g°K

Thermal Expansion¹⁰ $\alpha_a = 14.1 \times 10^{-6} / ^\circ\text{K}$
 $\alpha_c = 4.1 \times 10^{-6} / ^\circ\text{K}$

Resistivity¹⁴ $2 \times 10^{10} \Omega \cdot \text{cm} @ 200^\circ \text{C}$

Dielectric Constants¹⁶

$K_{11}^S = 43$ $K_{11}^T = 78$
 $K_{33}^S = 28$ $K_{33}^T = 32$

Loss tangent¹⁵ @400 °C

x-axis $\text{Tan}\delta = 0.0006$
y-axis $\text{Tan}\delta = 0.001$

Typical Polish Specifications

Wavefront Distortion: $\lambda / 8 @ 633 \text{ nm}$

Flatness: $\lambda / 10 @ 633 \text{ nm}$

Parallelism: 1 arcseconds

Scratch - Dig: 10 - 5

INRAD Lithium Niobate

Description

Lithium niobate is a ferroelectric material suitable for a variety of applications. Its versatility is made possible by the excellent electro-optic, nonlinear, and piezoelectric properties of the intrinsic material. It is one of the most thoroughly characterized electro-optic materials, and crystal growing techniques consistently produce large crystals of high perfection.

Applications that utilize the large electro-optic coefficients of lithium niobate are optical modulation and Q-switching of infrared wavelengths. Because the crystal is nonhygroscopic and has a low half-wave voltage, it is often the material of choice for Q-switches in military applications. The crystal can be operated in a Q-switch configuration with zero residual birefringence and with an electric field that is transverse to the direction of light propagation. Because piezoelectric ringing can be severe, piezoelectrically damped designs can be very useful. The damage threshold of the intrinsic material at 1.06 microns with a 10 nsec pulse is approximately 3 J/cm^2 . With appropriate AR coatings, a surface damage threshold of $300\text{-}500 \text{ MW/cm}^2$ can be achieved for the same conditions.

Applications that use the large nonlinear d coefficient of LiNbO_3 include optical parametric oscillation, difference frequency mixing to generate tunable infrared wavelengths, and second harmonic generation. With a broad spectral transmission, which ranges from $0.4 \text{ }\mu\text{m}$ to $5.0 \text{ }\mu\text{m}$ with an OH^- absorption at $2.87 \text{ }\mu\text{m}$, a large negative birefringence, and a large nonlinear coefficient, phasematching is an effective way to generate tunable wavelengths over a broad wavelength range.

Lithium niobate is particularly effective for second harmonic generation of low power laser diodes in the 1.3 to $1.55 \text{ }\mu\text{m}$ range.

For infrared generation by difference frequency mixing, the peak power limit is considerably lower than for $1.064 \text{ }\mu\text{m}$, being about 40 MW/cm^2 . Efficiencies for difference frequency mixing generally are smaller than shg efficiencies with KDP or BBO, which is due to the lower peak powers that can be tolerated by the crystal and the fact that the longer wavelength photons that are generated in the process are less energetic. Typical powers for 10 nanosecond long pulses with 5 mm diameter beams are 30 mJ/pulse of $0.640 \text{ }\mu\text{m}$ minus 40 mJ/pulse of $1.064 \text{ }\mu\text{m}$ to produce 2.5 mJ/pulse at $1.54 \text{ }\mu\text{m}$, and 32 mJ/pulse of $0.532 \text{ }\mu\text{m}$ minus 32 mJ/pulse of $0.640 \text{ }\mu\text{m}$ to produce 0.25 mJ/pulse at $3.42 \text{ }\mu\text{m}$.

INRAD offers lithium niobate in a variety of configurations. Standard cuts are available as OPO crystals, Q-switches, difference frequency mixing crystals, autocorrelation crystals, and optical waveguide wafers.

Please consult an INRAD sales engineer for assistance in crystal selection and packaging.

At INRAD, all crystal growth, orientation, fabrication, polishing, and testing of LiNbO_3 is done at one site so that you are assured of complete traceability and satisfaction with every crystal that you purchase.

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References

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