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	0.67 MPam$^{1/2}$
	x-face	1.07 MPam$^{1/2}$
	y-face	1.17 MPam$^{1/2}$

Elastic Compliance[4] at Constant Polarization (S_P) and at Constant Field (S_E) and Temperature Dependence[5]

$(\text{TPa})^{-1}$	(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 Constants[13]

$n = (A + B/(\lambda^2 + C) + D\lambda^2)^{1/2}$; λ 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 Values[13]

n_o(1.064 μm) = 2.2322 ; n_e(1.064 μm) = 2.1560
n_o(2.060 μm) = 2.1949 ; n_e(2.060 μm) = 2.1243
n_o(3.500 μm) = 2.1405 ; n_e(3.500 μm) = 2.0788

Photoelastic Strain Coefficients at Constant Field[11]

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

Temperature Variation of Refractive Index[13] for λ = 1.0 μm – 4.0 μm

$dn_o/dT = 3.3 \times 10^{-6}$ /°C
$dn_e/dT = 37 \times 10^{-6}$ /°C

Nonlinear d Coefficients[12,20]

d_{22} = 2.4 pm/V
d_{31} = -4.52 pm/V
d_{33} = 31.5 pm/V

Effective Nonlinear Optical Coefficient

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

Electro Optic Coefficients @ 0.633 μm[23]

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

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

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

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

Damage Threshold[2] 3 J/cm^2 @ 10 nsec

THERMAL AND ELECTRICAL PROPERTIES

Melting Point[7]	1240° C
Curie Temperature[8]	1145° C
Thermal Conductivity[9]	4. W/m°K
Thermal diffusivity[6]	9×10^{-7} m^2/sec
Specific Heat[9]	0.633 J/g°K
Thermal Expansion[10]	$\alpha_a = 14.1 \times 10^{-6}$ /°K $\alpha_c = 4.1 \times 10^{-6}$ /°K
Resistivity[14]	2×10^{10} Ω - cm @ 200° C

Dielectric Constants[16]

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

Loss tangent[15] @400 °C

x-axis Tanδ =0.0006
y-axis Tanδ =0.001

Typical Polish Specifications

Wavefront Distortion:	λ / 8 @ 633 nm
Flatness:	λ / 10 @ 633 nm
Parallelism:	1 arcseconds
Scratch - Dig:	10 - 5

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 300-500 MW/cm^2 can be achieved for the same conditions.

Applications that use the large nonlinear d coefficient of $LiNbO_3$ include optical parametric oscillaton, difference frequency mixing to generate tunable infrared wavelengths, and second harmonic generation. With a broad spectral transmission, which ranges from 0.4 μm to 5.0 μm with an OH^- absorption at 2.87 μm, 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 μm range.

For infrared generation by difference frequency mixing, the peak power limit is considerably lower than for 1.064 μm, being about 40 MW/cm^2. Efficiencies for difference frequency mixing generally are smaller than shg efficicncies 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 μm minus 40 mJ/pulse of 1.064 μm to produce 2.5 mJ/pulse at 1.54 μm, and 32 mJ/pulse of 0.532 μm minus 32 mJ/pulse of 0.640 μm to produce 0.25 mJ/pulse at 3.42 μm.

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.

References

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