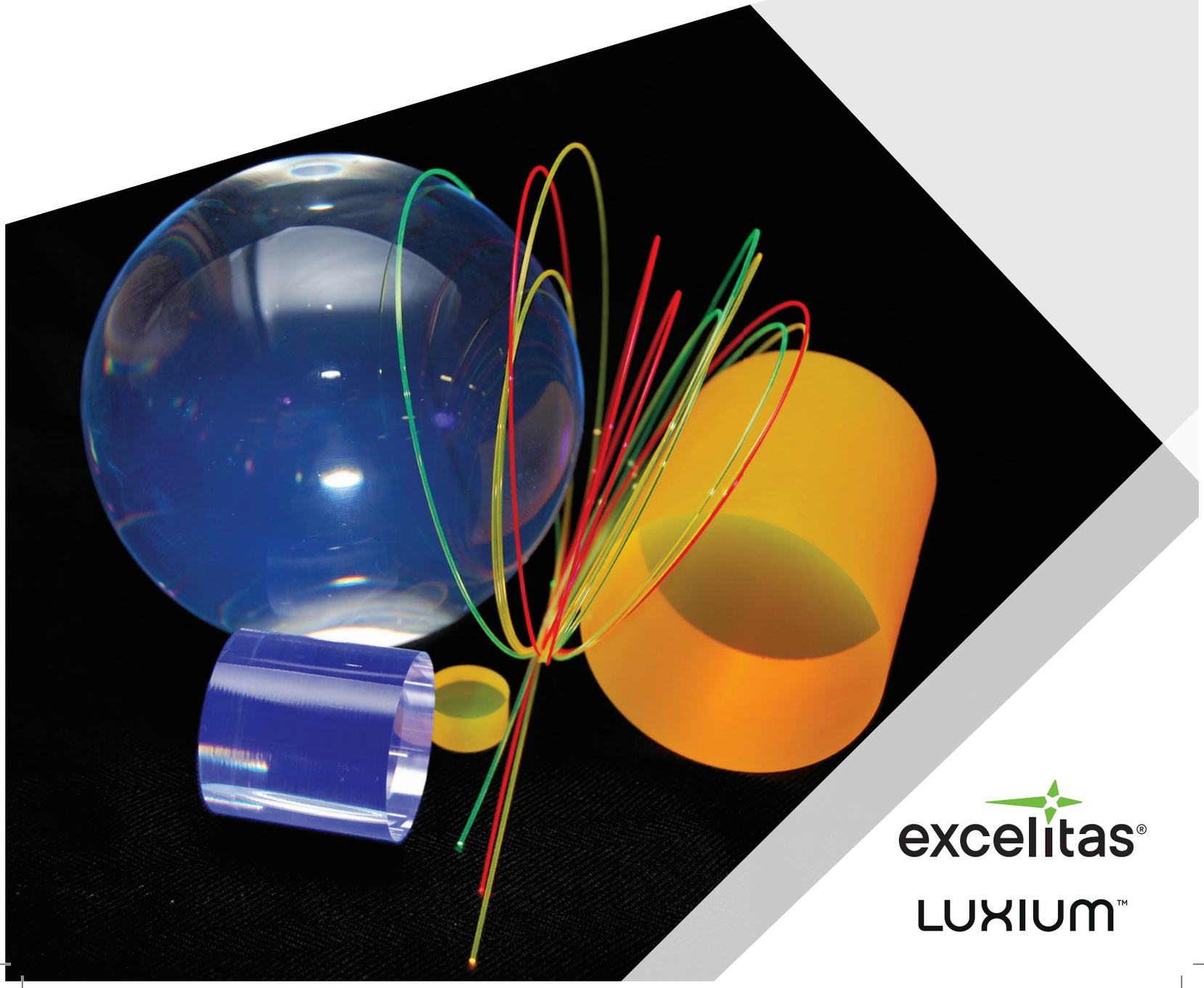
Luxium™ Organic Scintillation Materials and Assemblies



excelitas®

LUXIUM™

About Luxium™ Plastic Scintillators

Luxium™ Scintillation Materials & Assemblies build on the combined heritage of several pioneering companies in crystal growth, radiation detection, measurement technologies, and opto-mechanical products. This portfolio brings together decades of expertise from renowned brands including Bicron®, Crismatec®, Harshaw®, NE Technology® (inorganic and organic scintillators and detectors), Gamma Laboratories®, and Saphikon® (sapphire products).

Today, as part of Excelitas Technologies, the Luxium™ portfolio supports OEM customers and researchers worldwide by developing advanced scintillation products and radiation detection solutions for the Energy, Medical, Security, Industrial, Defense, and Semiconductor markets. These solutions enable customers to meet demanding performance requirements and develop innovative new applications.

This brochure presents the properties and features of our premium plastic scintillators, and related materials. All of our premium plastic scintillators are made of a base of polyvinyl toluene or styrene plus various fluors, which are selected to give each scintillator its characteristic response. Highly purified monomers are the bases for all of our materials, which assures maximum homogeneity and highest quality.

Individual product data sheets are available for each material type. Custom detectors using our plastic or combinations of our plastic and inorganic scintillators are available. We welcome your inquiry for special shapes or custom designs.

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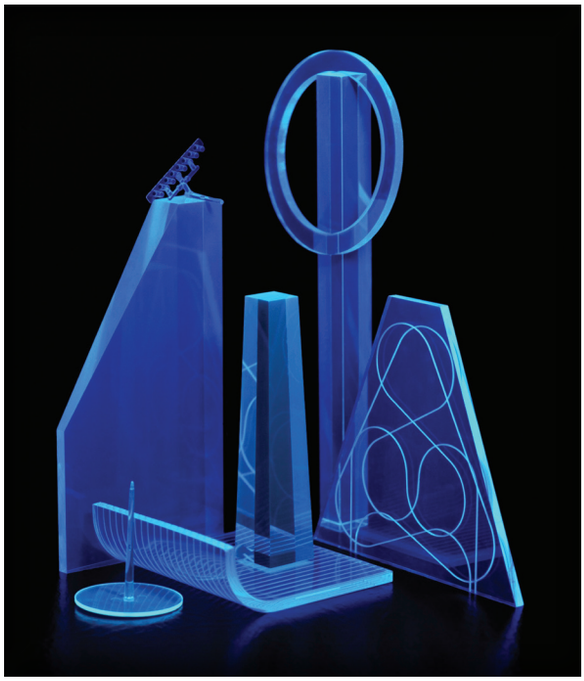
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Luxium™ Plastic Scintillators

General Description –

The scintillation emission of a typical plastic scintillator has a maximum around 425 nm. Plastic scintillators are characterized by a relatively large light output — typically 25-30% of NaI(Tl) — and a short decay time of around 2 ns. This makes the material suited for fast timing measurements.

All plastic scintillators are sensitive to X-rays, gamma rays, fast neutrons and charged particles.

Plastic scintillators are the most popular scintillation material for use in calorimeters, time of flight detectors, nuclear gauging and large area contamination monitors.

The exact emission wavelength and decay time depend on the type of organic activator and on the host material. A large number of different plastic scintillators are available, each for a specific application. General characteristics of plastic scintillators are presented in another section of this brochure.

Availability –

A plastic scintillator consists of a solid solution of organic scintillating molecules in a polymerized solvent. The ease with which they can be shaped and fabricated makes plastic scintillators an extremely useful form of organic scintillator. Our plastic scintillators are produced in a wide variety of shapes and sizes. Cast sheets are the most commonly used forms.

You also can obtain precision thin sheets, thin film, rods, annuli, ingots and large rectangular blocks.

We supply most solid scintillators with their surfaces prepared to optimize light collection. For cast sheets, the cast surfaces are untouched, and the edges are machined and polished or diamond milled.

Rods, annuli and blocks are machined and polished. Most applications require finished surfaces.

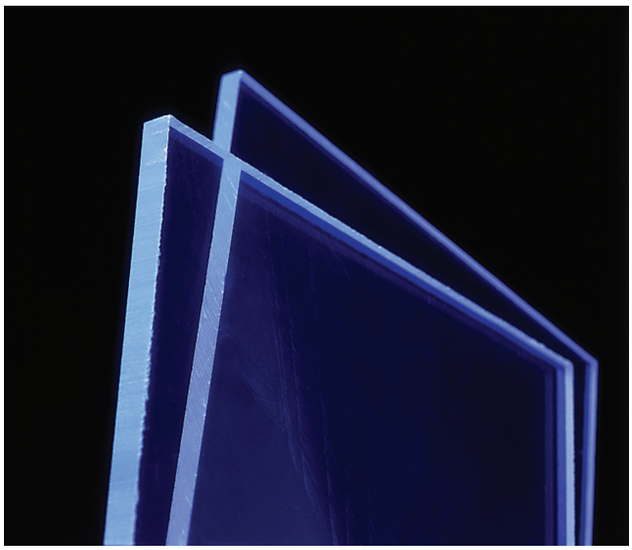
You can also obtain scintillators as finished detector assemblies. These incorporate light guides, photomultiplier tubes, special radiation entrance windows, and light tight wrappings (or metal housings).

Luxium™ Plastic Scintillator Applications Guide

Scintillator	Distinguishing Feature	Principal Applications
BC-400	NE-102 equivalent	general purpose
BC-404	1.8 ns time constant	fast counting
BC-408	best general purpose	TOF counters; large area
BC-412	longest attenuation length	general purpose; large area; long strips
BC-416	lowest cost	“economy” scintillator; large volume
BC-418	1.4 ns time constant	ultra-fast timing; small sizes
BC-420	1.5 ns time constant, low self-absorption	ultra-fast timing; for sheet areas > 100mm^2
BC-422	1.4 ns time constant	very fast timing; small sizes
BC-422Q	quenched; 0.7 ns time constant	ultra-fast timing, ultra-fast counting
BC-428	green emitter	for photodiodes and CCDs; phoswich detectors
BC-430	red emitter	for silicon photodiodes and red-enhanced PMTs
BC-440	high temperature up to 100°C	general purpose
BC-440M	high temperature up to 150°C	general purpose
BC-444	slow plastic, 285 ns time constant	phoswich detectors for dE/dx studies
Wavelength Shifter Bars		
BC-480	UV to blue waveshifter	Cerenkov detector
BC-482A	green emitter	waveshifter

Plastic Scintillators

Plastic sheets cast from the monomer ensure the highest light yield and best internal light transmission. All raw materials undergo extensive purification prior to polymerization and the finished sheets exhibit highly uniform scintillation and optical properties. Scintillators are machined to final dimensions using diamond tooling to provide optimum quality surfaces for total internal reflection.



Luxium™ Cast Sheet Sizes

Thickness*	Thickness Tolerance (nominal)	Routine Maximum**
0.5 mm	± 0.1 mm	30 x 60 cm
1 mm	± 0.1 mm	30 x 60 cm
1.5 mm	± 0.25 mm	30 x 101 cm
2 mm	± 0.25 /- 0.3 mm	45 x 101 cm
3 mm	0.38 mm	63 x 101 cm
5 mm	+ 0.56 / - 0.46 mm	63 x 203 cm
6.4 mm	+ 0.64 / - 0.51 mm	63 x 203 cm
10 mm	± 0.51 mm	63 x 203 cm
12.7 mm	± 0.64 mm	63 x 203 cm
20 mm	± 0.73 mm	63 x 203 cm
25 mm	+ 0.76 / - 1 mm	63 x 203 cm
38 mm	± 0.76 mm	63 x 203 cm
50 mm	± 2 mm	63 x 203 cm
75 mm	± 2.5 mm	60 x 101 cm
100 mm	± 3.8 mm	60 x 101 cm
125 mm	± 6 mm	60 x 101 cm
150 mm	± 6 mm	60 x 101 cm

* This dimension is controlled during the casting process

** Large sizes available, but with different tolerances

Special Large Cast Sheet

Thickness Range	Maximum Width	Maximum Length
1 - 5 cm	30 cm	450 cm
0.5 - 5 cm	45 cm	400 cm
0.5 - 5 cm	60 cm	300 cm
1 - 2.5 cm	100 cm	200 cm
1 - 3.8 cm	120 cm	120 cm

Please ask about other special sizes you may need

Thin Films –
Thin films are ideally suited for charged particle detection.

Thin Film Specifications (Typical Size) BC-400B

Thickness Range	Tolerance Range	Sheet Size W x L
.15 mm	± 10%	150 x 350 mm
.20 mm	± 10%	150 x 350 mm
.25 mm	± 10%	150 x 350 mm

- Edges are trimmed or polished (upon request)

Optical Plastic Components

Light guides are used to convey scintillation photons to the readout device. Key performance parameters are good optical transmission across a broad range of wavelengths and highly polished surfaces to promote total internal reflection. All light guides are custom designed to suit the particular scintillator geometry and experimental constraints.

Light Pipes –

Plastic light pipes often are used with plastic and liquid organic scintillators to:

- Provide a PMT mounting surface
- Guide the scintillating light to the photocathode
- Back-off the PMT where the scintillator is in a strong magnetic field
- Minimize pulse height variation

Typical light pipe geometries include:

- Right Cylinders - used when the light pipe diameter is the same as the scintillator diameter
- Tapered Cones - are transition pieces between square-to-round or round-to-round cross-section
- “Fish Tail” - are transition pieces from thin, rectangular cross-sections to round cross-sections
- Adiabatic - provide the most uniform light transmission from the scintillator exit end to the PMT; the cross-sectional areas of the input and PMT faces are equal

We recommend that, for scintillators <6 mm thick, a fish tail light pipe have a groove machined into its edge which joins the scintillator. The scintillator edge fits into the groove to improve the mechanical strength of the joint. Also, a disk which matches the diameter of the PMT is coupled to the light pipe’s other end to act as the PMT mounting surface.

The length of a fish tail or adiabatic light pipe is generally equal to the width of the scintillator, for scintillators 15.2 cm wide or greater.

The light pipe materials we use include:

- BC-800 UVT acrylic - for scintillators with emission spectra in the near UV, such as NaI(Tl), BC-418, BC-420 and BC-422
- BC-802 general purpose, non-UVT, PMMA plastic - for most scintillators



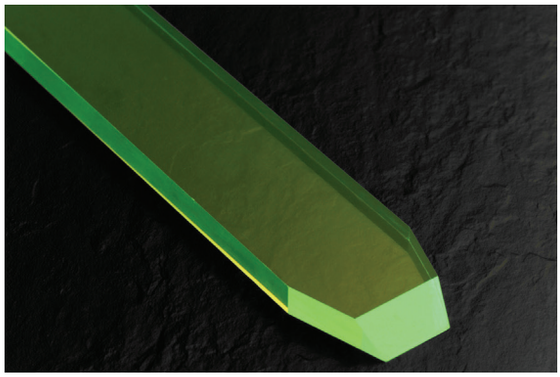
Wavelength Shifter Bars –

Wavelength shifter (WLS) plastic bars absorb light at one wavelength and emit it isotropically at a longer wavelength. A portion of the re-emitted light is transmitted by total internal reflection along the WLS bar to be read out at the ends.

Often used with scintillator shower stacks, single WLS bars are air-coupled to a stack or plane of scintillator strips. The scintillation light is essentially turned 90° in a very compact structure. However, there is a typical 75% loss of signal amplitude in such a system.

We make wavelength shifter bars from PVT-based materials. These include:

- BC-480 - shifts from near UV (300-360 nm) to 425 nm
- BC-482A - shifts from 420 to 500 nm; for use with BC-408 and BC-412 plastic scintillators





Detector Assembly Material

Optical Interface, Wrapping Materials

BC-634A Optical Interface Pad –

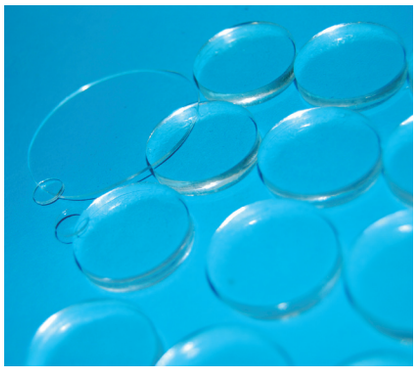
BC-634A is a silicone-adhesive coupling compound for making an optically clear bond between the scintillator and photomultiplier tube. BC-634A is formulated for use within the temperature range of -10 to +60°C, has an index of refraction of 1.42 and a typical transmission of approximately 93% at 400nm.

BC-634A is a self-wetting, flexible pad just hard enough to resist tearing while handling.

If you cannot maintain sufficient interface pressure, apply a thin film of coupling grease to both sides of the interface pad.

BC-637 High Temperature Optical Interface Pad –

BC-637 is a silicone-adhesive coupling compound for making an optically clear bond between the scintillator and photomultiplier tube. BC-637 is rated to 200 C.



BC-638 Black Wrapping Tape –

BC-638 is a black adhesive tape 2" (50.8mm) wide by .008" (0.2mm) thick. Wrapping a plastic scintillator in one layer will give you a light-tight seal. We provide BC-638 in 36 yard (32.9m) rolls.

BC-640 Plastic Masking Paper –

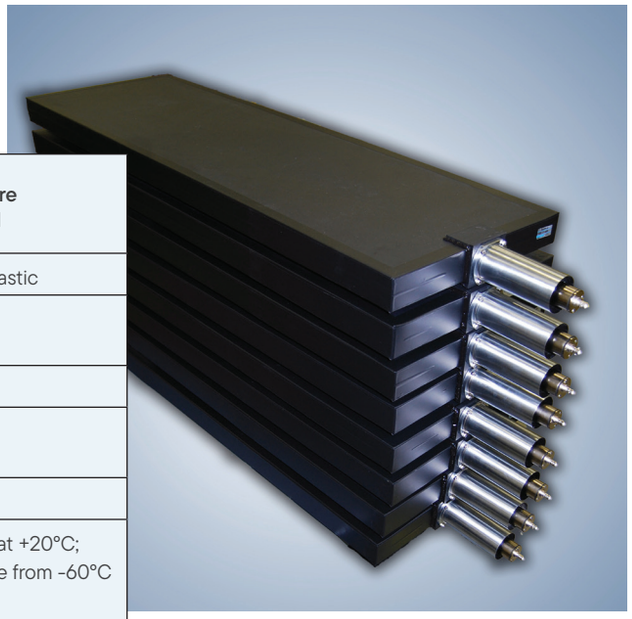
This material is an adhesive-backed masking paper routinely used for protecting the surfaces of plastic scintillator during handling or storage. We supply BC-640 in rolls 12" (30.5cm) wide by 300' (91.4m) long.

BC-642 PTFE Reflector Tape –

BC-642 is a .003" (0.08 mm) thick (normal) Teflon tape and is frequently used as a reflecting material for non-hygroscopic scintillators. Three layers give you optimum reflectivity. It comes in rolls 2" (50.8mm) wide by 540" (13.7m) long.

Technical Data

General Characteristics



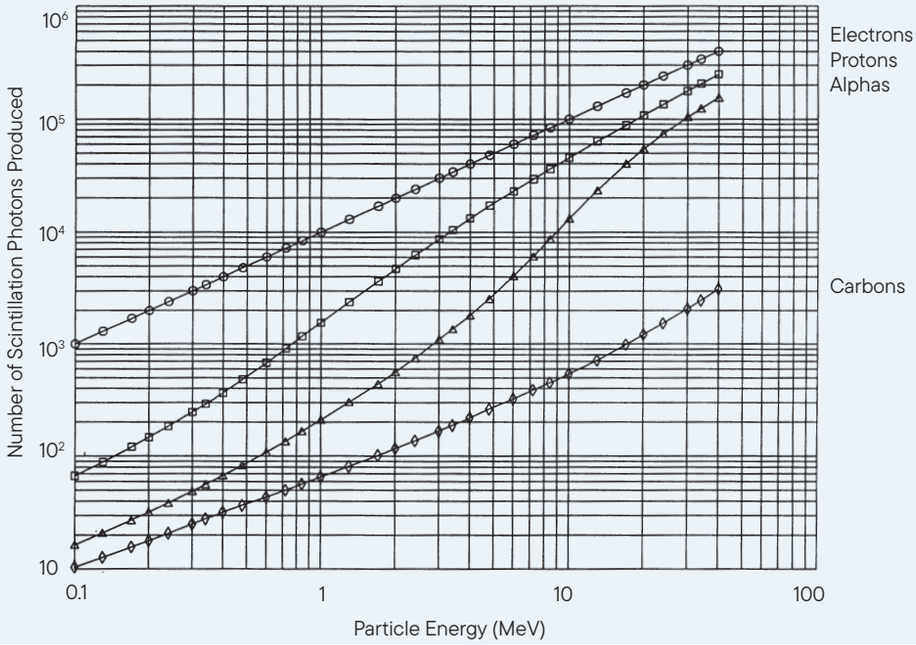
Scintillators	General Purpose BC-400, 404, 408, 412, 416, 418, 420, 422, 430,444,	High Temperature BC-440, 440M
Base	Polyvinyltoluene	Special aromatic plastic
Density	1.03	≈1.04
Refractive Index	1.58	1.58
Coefficient of Linear Expansion	7.8 x 10^{-5}/°C, below 67°C	
Atomic Ratio, H/C	≈1.1	≈1.1
Light Output	At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°	At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°C. At 150°C, light output is 84% of that at room temperature (BC-438)
Vapor Pressure	May be used in vacuum	
Solubility	Soluble in aromatic solvents, chlorine, acetone, etc; insoluble in water, dilute acids, lower alcohols, silicone fluid, grease and alkalis.	

Structural Properties of BC-408 Premium Plastic Scintillator (Characteristic of all of our PVT-base Scintillator Materials)

		Thickness	
Property	**Test Procedure**	**50 mm**	**150 mm**
Yield Strength MPa	ASTM D638	30.8	28.3
Breaking Strength MPa	ASTM D638	30.8	28.3
Tensile Modulus MPa	ASTM D638	2700	3010
Flexural Strength MPa	ASTM D790	45.6	40.5
Flexural Modulus MPa	ASTM D790	2920	2700
Compressive Strength MPa	ASTM D695	38.1	40.5
Compressive Molulus MPa	ASTM D695	1380	2700
Shore “D” Hardness	ASTM D2240	84	84

1 MPa (megapascal) = 145 psi = 10^6 Nt/m^2

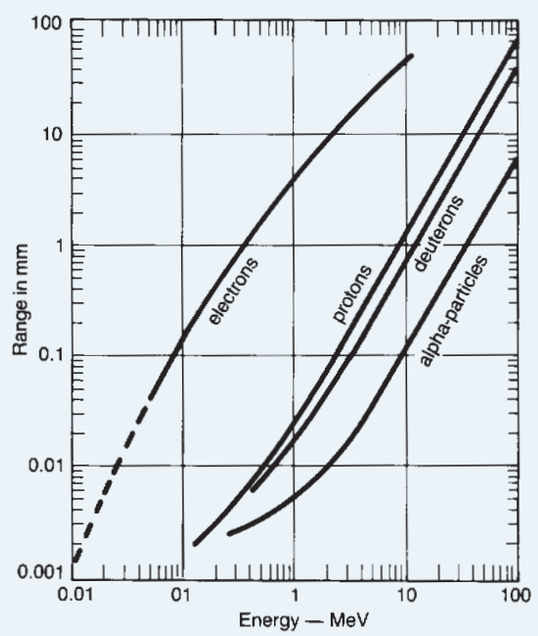
Response of BC-400
Scintillation Light Produced vs. Particle Energy



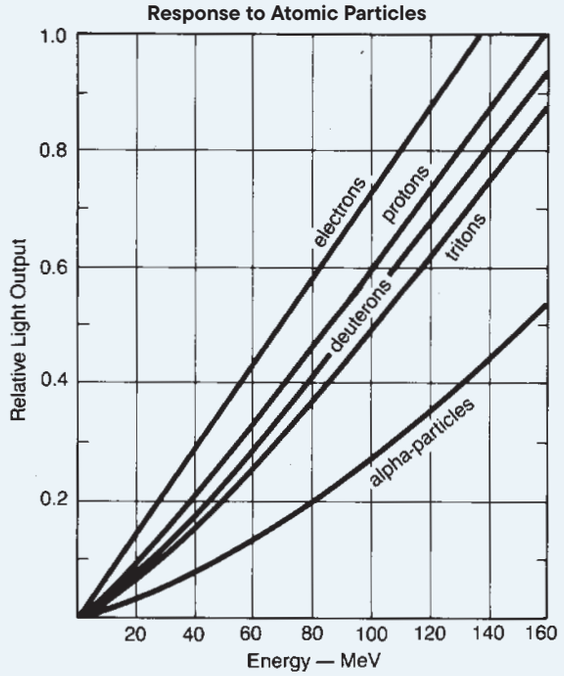
Technical Data

Light Output, Light Collection

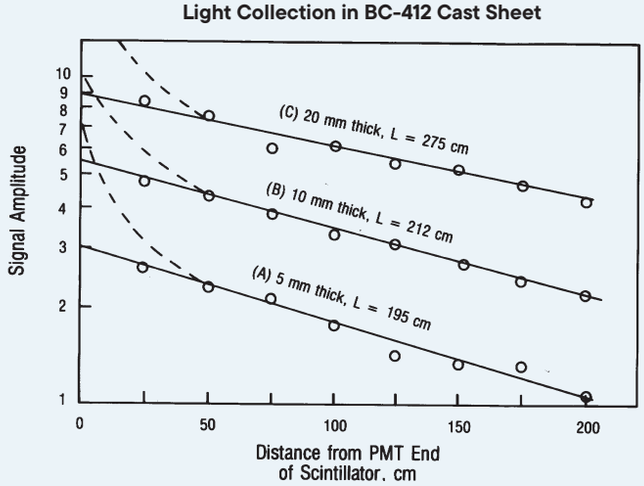
Range of Atomic Particles in Premium Plastic Scintillator



Premium Plastic Scintillator Response to Atomic Particles



Light Collection in BC-412 Cast Sheet



Sheet Size: 120 mm x 2000 mm
(4.71"x 80")

- Plot of Technical Attenuation Length using a 150 mm (6") long, triangular light guide connecting the scintillator to the phototube.
- Approximate result when the phototube is coupled directly to the scintillator.

Technical Data

Light Attenuation Coefficients

Light Attenuation Lengths for Plastic Scintillators

The Technical Light Attenuation Length (TAL) of a plastic scintillator is defined as the length required to reduce the signal amplitude by 1/e. It is applied to scintillator sheets and rods having lengths of a meter or more, and where total internal reflection is a major factor in the light collection process.

These factors contribute to attenuation length for a given scintillator sheet:

a. Bulk transmission of the material
b. Thickness and shape
c. Reflective properties of the surfaces

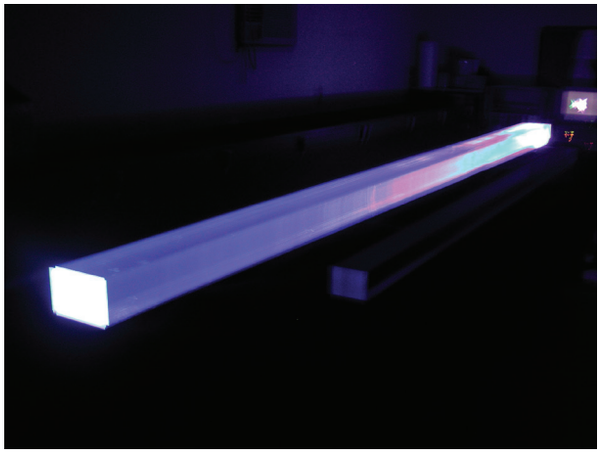
The use of light guides and reflectors also can alter the measured attenuation length of a plastic scintillator counter assembly. The effect of thickness on the measured TAL is demonstrated by the following data on 12 cm wide x 200 cm long sheets of BC-408:

5 mm thick TAL = 190 cm
10 mm thick TAL = 210 cm
20 mm thick TAL = 275 cm

This data was taken using a 50 mm diameter, bialkali photomultiplier tube coupled to one end of the scintillator by a light guide and with the opposite end of the scintillator blackened. In actual practice, however, the far end is not blackened. This results in much better light collection performance.

The following are typical bulk attenuation lengths for our premium plastic scintillators used in long sheets:

BC-400	250 cm
BC-404	160 cm
BC-408	380 cm
BC-412	400 cm
BC-416	400 cm
BC-420	110 cm
BC-440	400 cm



Gamma Attenuation Coefficients for Plastic Scintillators

keV	μ_l(cm^{-1})	keV	μ_l(cm^{-1})
10	1.90	360	0.112
12	1.23	380	0.110
14	0.780	400	0.107
16	0.620	420	0.105
18	0.490	440	0.103
20	0.400	460	0.102
25	0.290	480	0.100
30	0.250	500	0.0980
35	0.230	550	0.0941
40	0.215	600	0.0907
45	0.200	650	0.0874
50	0.196	700	0.0845
55	0.189	750	0.0822
60	0.186	800	0.0800
65	0.183	850	0.0777
70	0.180	900	0.0754
75	0.178	950	0.0734
80	0.176	1000	0.0715
85	0.174	1200	0.0658
90	0.172	1400	0.0606
100	0.167	1600	0.0561
120	0.160	1800	0.0522
140	0.154	2000	0.0494
160	0.149	2200	0.0465
180	0.143	2400	0.0437
200	0.138	2600	0.0414
220	0.134	2800	0.0394
240	0.130	3000	0.0378
260	0.126	3200	0.0363
280	0.123	3400	0.0352
300	0.121	3600	0.0335
320	0.118	3800	0.0323
340	0.115	4000	0.0312

Physical Constants of Luxium™ Plastic Scintillators

Scintillator	Light Output % Anthracene[1]	Wavelength of Maximum Emission, nm	Decay Constant, ns	Bulk Light Attenuation Length, cm	Refractive Index	H:C Ratio	Loading Element % by weight	Density [g/cc]	Softening Point °C
BC-400	65	423	2.4	250	1.58	1.103		1.023	70
BC-404	68	408	1.8	160	1.58	1.107		1.023	70
BC-408	64	425	2.1	380	1.58	1.104		1.023	70
BC-412	60	434	3.3	400	1.58	1.104		1.023	70
BC-416	38	434	4.0	400	1.58	1.110		1.023	70
BC-418	67	391	1.4	100	1.58	1.100		1.023	70
BC-420	64	391	1.5	110	1.58	1.102		1.023	70
BC-422	55	370	1.6	8	1.58	1.102		1.023	70
BC-422Q	11	370	0.7	<8	1.58	1.102	Benzephenone,0.5%*	1.023	70
BC-428	36	480	12.5	150	1.58	1.103		1.023	70
BC-430	45	580	16.8	NA	1.58	1.108		1.023	70
BC-440	60	434	3.3	400	1.58	1.104		1.023	99
BC-440M	60	434	3.3	380	1.58	1.104		1.023	100
BC-444	41	428	285	180	1.58	1.109		1.023	70
BC-480	**	425	–	400	1.58	1.100		1.023	70
BC-482A	QE=.86	494	12.0	300	1.58	1.110		1.023	70

[1] Anthracene light output = 40-50% of NaI(Tl) * 0.1 to 5 weight % also available ** Ratio of Cerenkov light to scintillator light = 10:1

The data presented are believed to be correct but are not guaranteed to be so. Nothing herein shall be construed as suggesting the use of our product in violation of any laws, regulations, or rights of third parties. User should evaluate suitability and safety of product for user's application. We cannot assume liability for results that user obtains with our products since conditions of use are not under our control.

Handling, Care and Safety

Premium plastic scintillators are shipped with a protective masking paper, or, on request, with a clear plastic film applied to the scintillator surfaces. This protective layer should be left on the scintillator during all handling until just before it is wrapped with reflective light tight covers prior to installation in your detector system.

These protective materials adhere to the scintillator by means of a low-tack adhesive which leaves little or no residue when the mask is removed. The adhesive is sufficiently weak so that, once it is removed, the masking tape will not stick to the scintillator again.

The scintillators and light guides are machined without the use of standard cutting oils. Water is usually the only lubricant employed. After being polished, the scintillators and light guides are cleaned thoroughly to remove all residues of polishing compounds and optical cements.

1. Keep the factory-applied, protective masking material on the scintillator as long as possible. Avoid wetting the protective paper as this may cause the paper to come off and leave the adhesive attached to the scintillator.
2. When handling bare scintillator, wear clean soft cotton gloves. If this is not possible, wash your hands to remove any oils. The normal body oils could damage the scintillator.
3. Protect the scintillator from exposure to most organic solvents and their vapors. The one exception to this rule is the lower alcohols: methanol, ethanol and isopropanol. Use only reagent grade alcohols. Isopropanol is preferred because of the less intense cooling that accompanies evaporation.
4. Clean water and soapy water followed by a clean rinse are the best solvents for cleaning the scintillator, especially when cleaning large areas. A solution of about 10 grams of Alconox in a gallon of water is recommended. After water washing, the scintillator may be blown dry with oil-free compresed air or gently patted dry with clean, soft, non- abrasive cloths or paper towels.

   Alcohols are best employed to clean areas such as around epoxy joints.

Reference the Material Safety Data Sheet included with your scintillator shipment for specific instructions.

In general:

1. WEAR PROTECTIVE GLOVES
2. VENT ROOM
3. EXTINGUISH ALL FLAMES

Luxium™ Plastic Scintillators are produced under a Quality Management System for design and manufacturing of chemical compounds, crystals, and detectors, which complies with the requirements of ISO 9001:2015

For additional product literature or information, call customer service at any of our locations or access our website document library – www.luxiumsolutions.com.
Other radiation detection products available include:

- Inorganic scintillators including NaI(Tl), CsI, $CdWO_4$, $LaBr_3$ and LYSO – configured as solids or arrays with or without an integrated light-sensing device.



It's what's Inside that Counts®

Worldwide locations:

- Bengaluru, India
- Beijing, China
- Gieres, France
- Hiram, Ohio
- Milford, New Hampshire
- St.-Pierre-les Nemours, France
- Tokyo, Japan

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