Inradoptics

Production of Stilbene for Fast Neutron Detection

Prototype quantities of stilbene scintillation crystals are now available from Inrad Optics. Larger quantities and sizes will be offered as refinements continue to be made in production techniques. The organic scintillator stilbene has long been recognized as an excellent material for detection of fast neutrons in a gamma-ray background, but material availability at a reasonable price has limited its widespread use. Today, that limitation is beginning to be addressed. Over the past two years, Inrad Optics has demonstrated steady improvement in crystal size, quality, and performance metrics. Presently, performance of crystals being manufactured at Inrad Optics matches or exceeds the best ever reported.

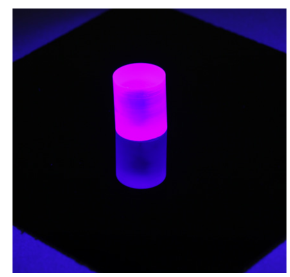
1" and 2" diameter stilbene cylinders

APPLICATIONS

Fast neutron detection has applications in medicine, industry, research, defense, and homeland security. Advantages of stilbene are high sensitivity to fast neutrons (generally above ~1 MeV kinetic energy) and excellent discrimination between fast neutrons and gamma-ray radiation. Additionally, stilbene is a solid-state, non-hazardous material. These attributes support neutron measurements and spectroscopy for detection and characterization of neutron fields associated with nuclear reactors, industrial and research neutron sources, and certain special nuclear materials.

The scintillation light pulse emitted from many organic scintillators consists of both a prompt and a delayed fluorescence.[i] The fraction of light resulting from the slow component often depends on the type of particle interacting with the crystal. Pulse shape discrimination (PSD) methods exploit this effect to separate events arising from neutrons and gamma-rays. Only a few materials exhibit a difference in decay rates sufficiently large for efficient counting of fast neutrons in a gamma background.

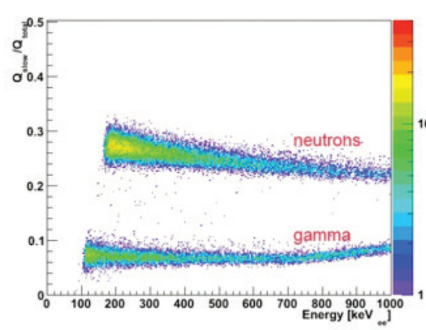
Pulse shape discrimination data can be presented as a 2D plot showing the separation of neutron and gamma-ray peaks as a function of energy. The energy scale is presented in units of keVee (keV electron equivalent) to account for the particle-dependent variation in light output per keV deposited in the scintillator. One metric for evaluating scintillators is the neutron-gamma discrimination figure of merit (FOM), calculated using data over a specified energy range on the PSD plot.



Stilbene cylinder under UV light illumination.

$$FOM = \Delta_{gn} / (FWHM_{gamma} + FWHM_{neutron})$$

In this equation Δ_{gn} is the separation between the gamma-ray and neutron peaks and FWHM is the full-width at half maximum of the relevant peak. The pulse shape discrimination plot of Inrad Optics stilbene shows exceptional neutron-gamma separation, with a FOM of 4.7 for energies between 412 and 562 keVee. This value is equivalent to the FOM for melt-grown stilbene and is superior to values reported for other commercially-available materials, such as liquid and plastic scintillators.



Pulse shape discrimination pattern from Inrad Optics stilbene obtained with a ^{252}Cf source. Data courtesy of Natalia Zaitseva, LLNL.

COMPARISON: LARGE-SCALE PRODUCTION OF UV FILTER CRYSTALS AT INRAD OPTICS

Among our primary solution-grown products are nickel sulfate-based crystals, which are used as solar-blind UV filters. Over the past decade, Inrad Optics has produced over 30,000 individual filter elements of this crystal for one major defense contractor, which required growth of over 1,200 individual crystals.

Each element was cut to size, polished, and packaged in-house at our Northvale facility. By applying a similar combination of high-quality solution crystal growth and in-house fabrication expertise, Inrad Optics intends to produce organic scintillators in quantities that meet the needs of the radiation detection community.

Solution-grown crystal and polished UV filter optics.

SOLUTION CRYSTAL GROWTH OF STILBENE AND PRODUCTION

Using technology originally developed for growth of extremely large crystals of potassium dihydrogen phosphate (KDP) for the National Ignition Facility, Lawrence Livermore National Laboratory researchers demonstrated that organic scintillation crystals can be grown from solution.[ii] This opened up new possibilities for the field of radiation detection, since traditional melt-grown organic scintillation crystals have size and availability limitations. Crystal growth of inorganic crystals from low-temperature solutions is an established commercial process; skilled practitioners can scale their operation to produce significant quantities of high quality material. Examples include KDP, nickel sulfate, and barium nitrate, all of which are grown at Inrad Optics.

We use a low-temperature solution growth method to produce crystals of high-purity stilbene. In this process, a crystallizer is loaded with a seed and a solution consisting of stilbene raw material dissolved in an organic solvent. The crystal grows out from the seed as the temperature of the solution is reduced in a controlled manner. All of our crystallizers are custom-designed to withstand attack by organic solvents, minimize loss of volatile solvent, and facilitate growth of high-quality crystalline material. Excellent material quality is demonstrated by the narrow X-ray rocking curves of the (100) face, which yields a symmetric peak with FWHM of approximately 17 arc-seconds.

We have fabricated stilbene crystals into a variety of shapes and dimensions. If desired, stilbene surfaces can be ground and polished. We have produced 1" and 2" diameter cylinders with lengths up to 4". We also have produced thin disks, thin plates, and thick slabs up to 4" in diameter. Parts with custom dimensions can be fabricated to customer specifications. We anticipate scaling to larger diameter cylinders during 2014.

CONCLUSIONS

We are pleased to announce the commercial availability of single-crystal stilbene optical elements. Inrad Optics' stilbene demonstrates excellent characteristics for use in fast neutron detection in a gamma background. Growth of stilbene from a low-temperature solution offers a compelling alternative to standard melt-grown crystals for large-scale production of stilbene. Processes have been developed for crystal growth and fabrication of stilbene cylinders up to 2"x4". Please contact our sales department with your inquiries.

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i G.F. Knoll, Radiation Detection and Measurement, New York, 2010.

ii N. Zaitseva, L. Carman, A. Glenn, J. Newby, M. Faust, S. Hamel, N. Cherepy, S. Payne, "Application of solution techniques for rapid growth of organic crystals", J. Crystal Growth 314 (2011) 163; US Patent Pub. No.: US 2010/0252741 held by Zaitseva et al.