SAND2022-12616C

Sandia National Laboratories

Exceptional service in the national interest

Melt-Blending: A Tool To Simplify Plastic Scintillator Production

Nicholas Myllenbeck*, Annabelle I. Benin, Huu M. Tran, Ryan J. Witzke, Patrick L. Feng

Sandia National Labs; Livermore, CA

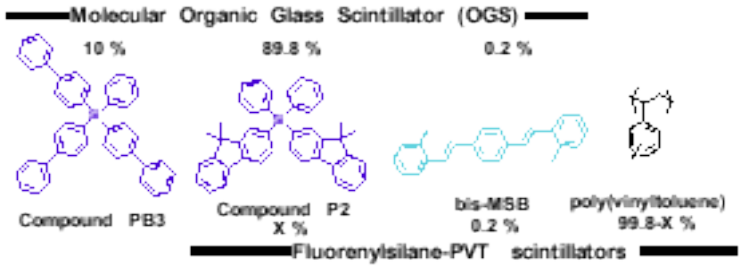
SCINT 2022, Los Alamos, New Mexico

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

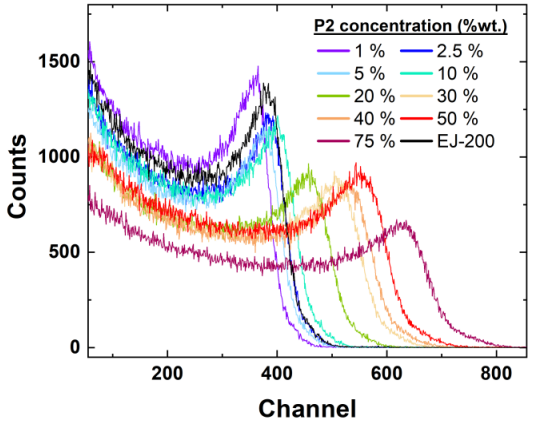
Comparison of Organic Scintillators

	trans-Stilbene	Organic Glass Scintillator (OGS)	40 % OGS-PVT	EJ-276D	EJ-200
Type	Single crystal	Amorphous	Amorphous blend	Amorphous blend	Amorphous blend
Production	Single crystal growth	Melt-cast to shape	Melt-cast to shape	Melt-cast to shape*	Melt-cast to shape*
Gamma-ray Light Yield	15,000 photons/MeV	18,400 photons/MeV	14,300 photons/MeV	10,200 photons/MeV	10,000 photons/MeV
γ/n PSD FoM (1" cylinder)	3.28	2.67	2.18	1.52	0.58

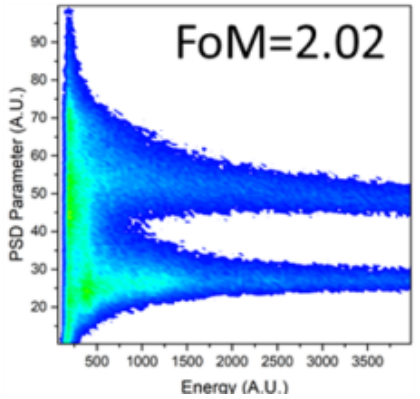


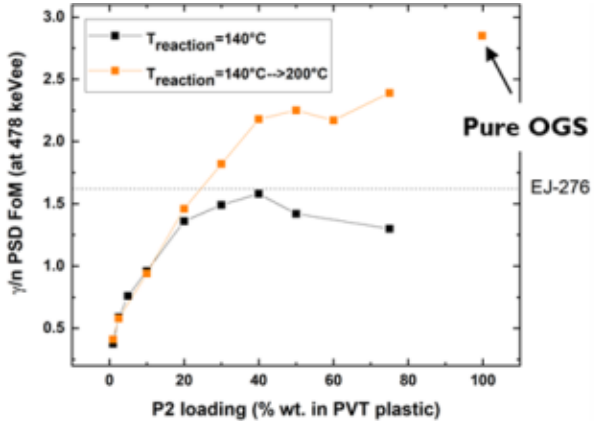
P2 and PVT/PS are miscible

In-situ polymerized OGS/PVT blends

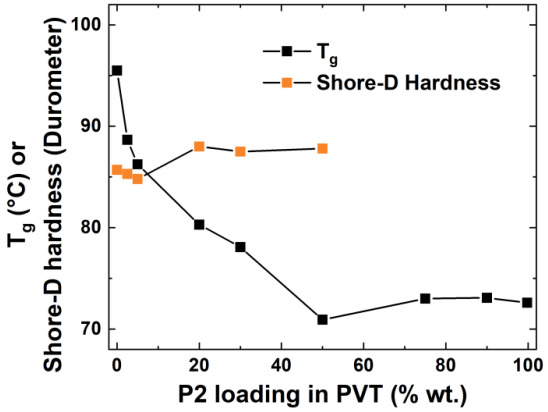


Gamma-ray light yield ~linear with [P2] in 1" samples





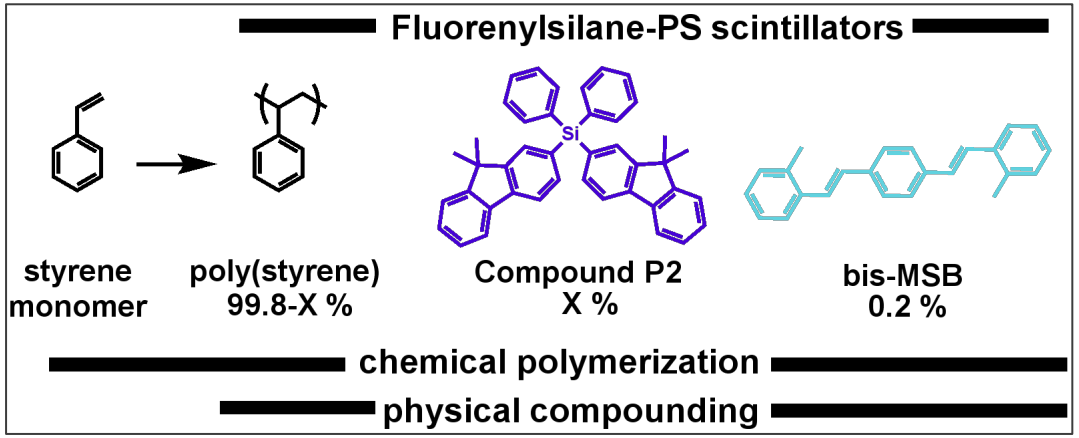
Neutron/gamma PSD



Stable T_g and Durometer hardness with [P2]

Manufacturing Methods: Chemical Polymerization vs. Physical Compounding

Can we reduce the complexity of monolithic plastic scintillator production using widely-practiced thermoplastic manufacturing methods?

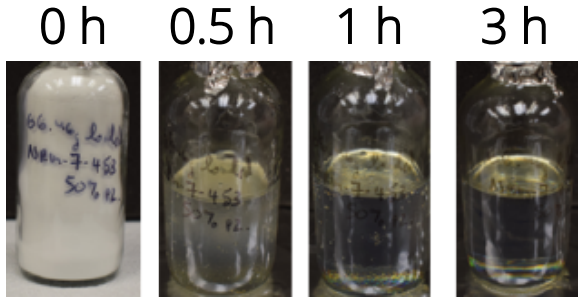


Process	Description	Attributes
Chemical Polymerization	Dissolve fluors + additives in monomer, convert monomer to polymer under inert atmosphere	Time: 7-14 days typical Basis: air-free, wet chemistry Additives: Avoid radical quenchers, straightforward blending Polymer Structure: Copolymers and crosslinking straightforward Purity: ~0.25 % residual monomer minimum Molding: glass, with few exceptions
Physical Compounding	Powderize polymer, blend in solid state with additives, melt under inert atmosphere	Time: 0.5-3 days Basis: solid-state mixing of commercially available ingredients Additives: Similar scope to CP, but radical quenchers tolerated, multiple melt cycles possible Polymer Structure: Thermoplastics only Purity: additive-free polymers best, low residual monomer Molding: glass + high temp. polymers (e.g. silicone, PTFE)

Physical Compounding Process Flow: Two Methods

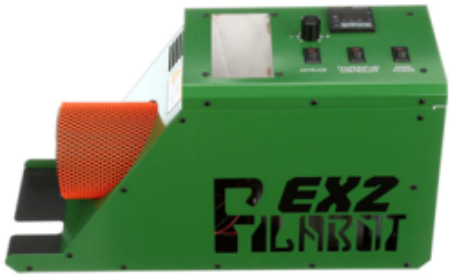
Ground polymer + additives

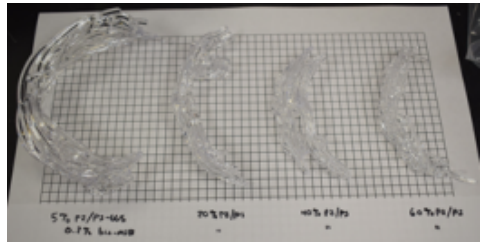
Direct melt-blending



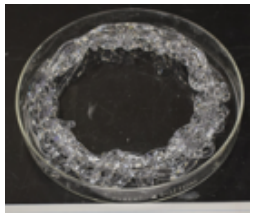
Melt at high temp. under inert atmosphere, obtain ≤ 5 % composition gradient*

1. Extrusion,
2. Melt-blending

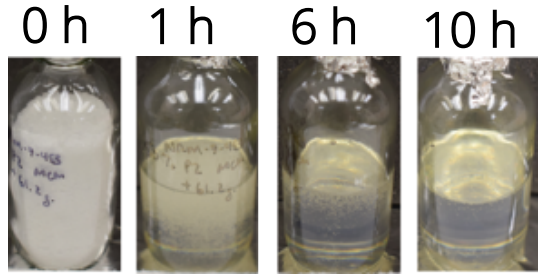




Extrude filament

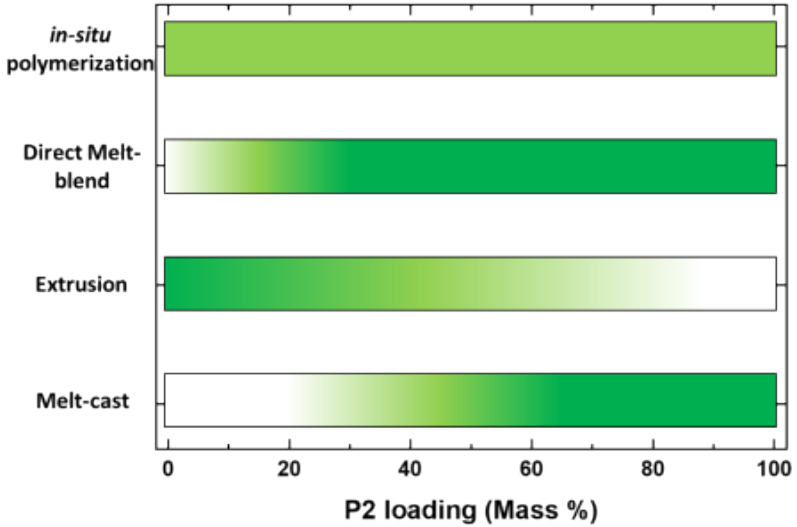


Grind to ~1 mm particles



Melt at high temp. under inert atmosphere, obtain ≤ 5 % composition gradient

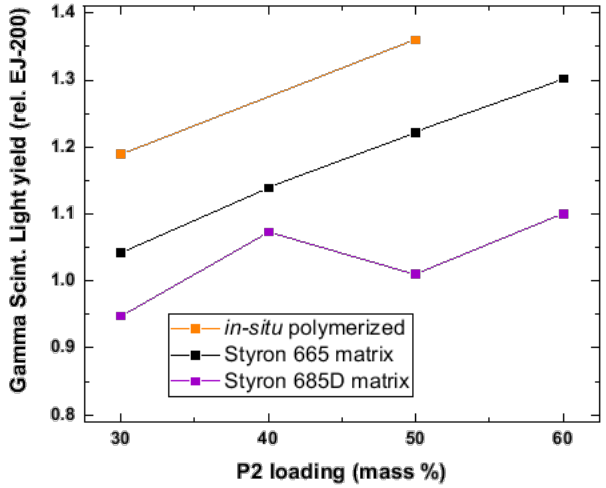
Qualitative Ease of Manufacture by Method

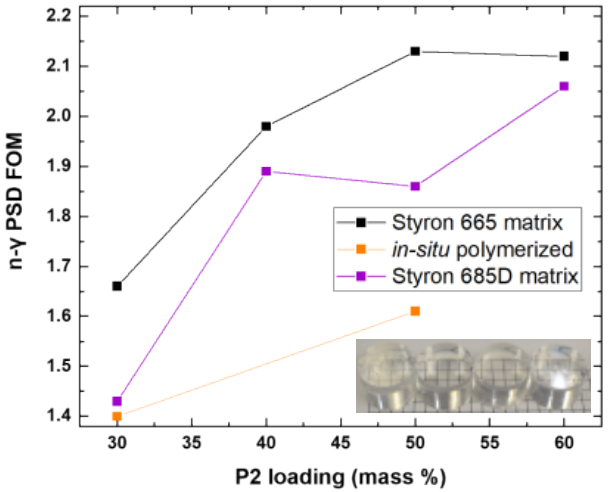


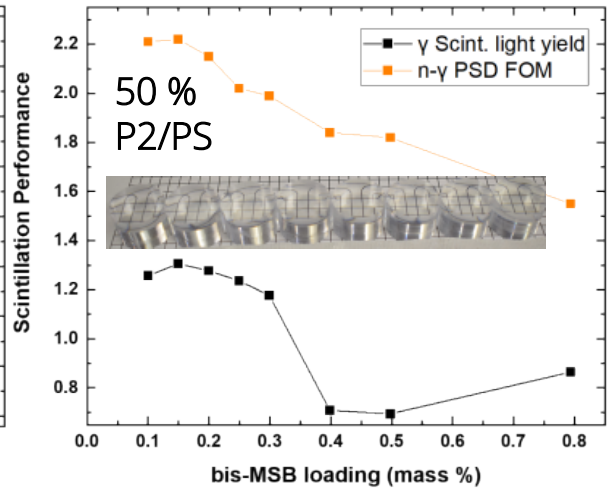
Scintillator Characterization

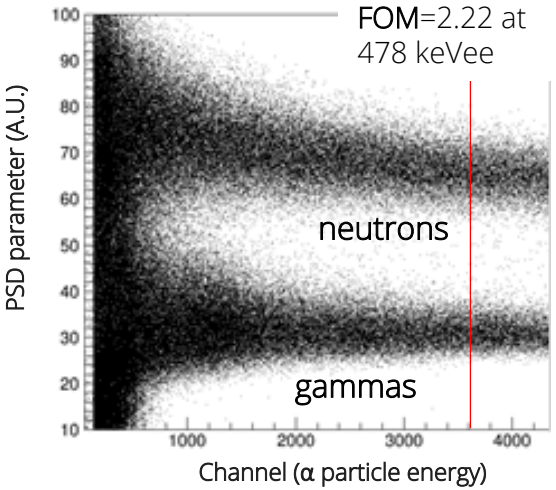
Detector Performance (1" Ø x 0.5" tall cylinders)

- *In-situ* polymer blends have better gamma-ray light output, but n/γ PSD is significantly enhanced for melt-blends

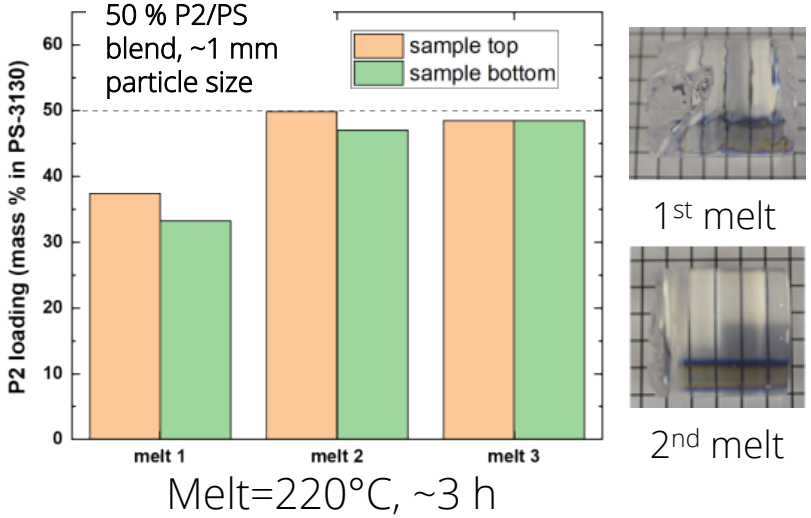




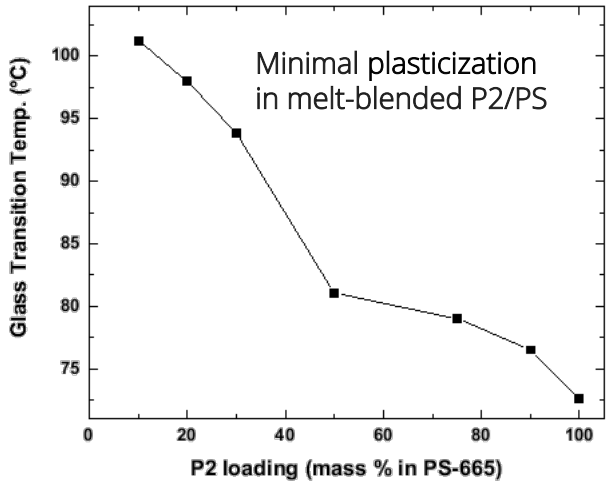




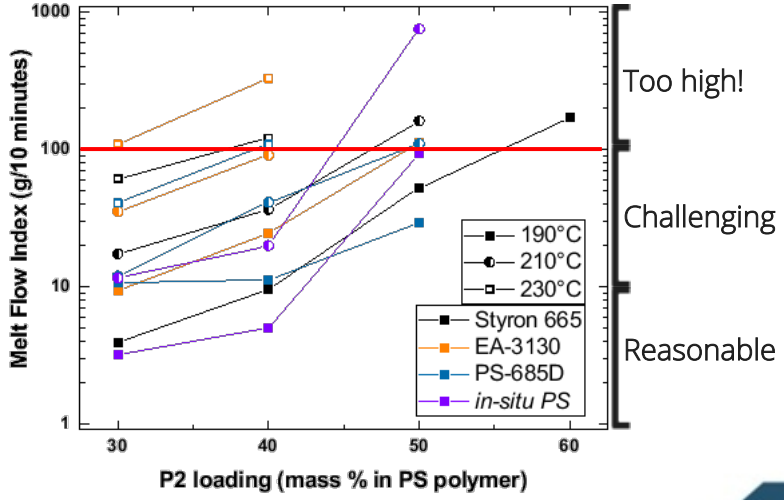
Composition *via* NMR



Differential Scanning Calorimetry

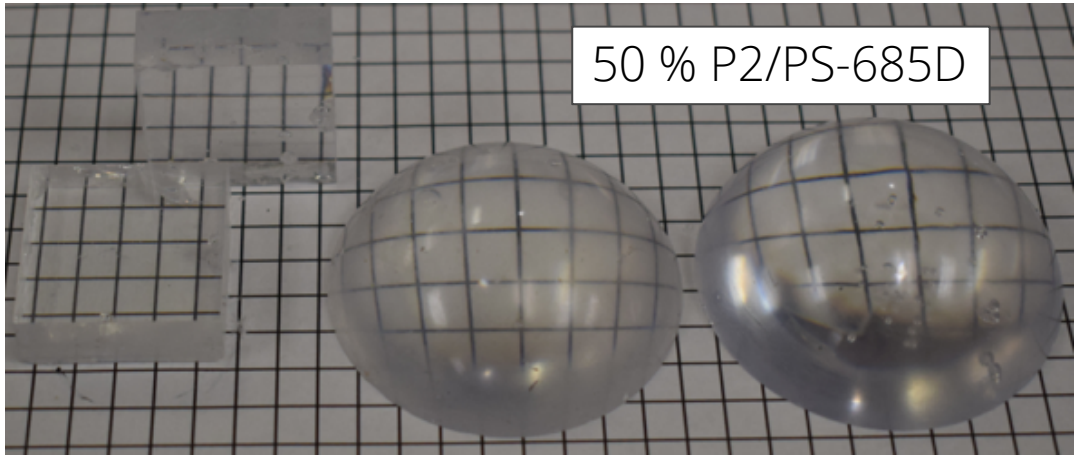


Melt Flow Index



Challenging Form Factors, Scale-up, and Other Formulations

Non-traditional form factors achieved with silicone molds

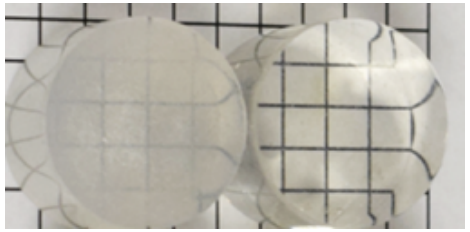


1″ square prisms ~2″ hemispheres

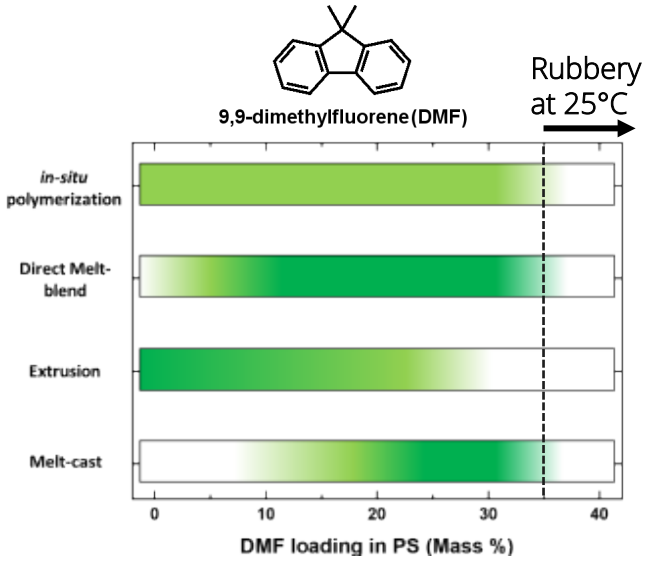
<u>Non-fogging plastic scintillators</u>

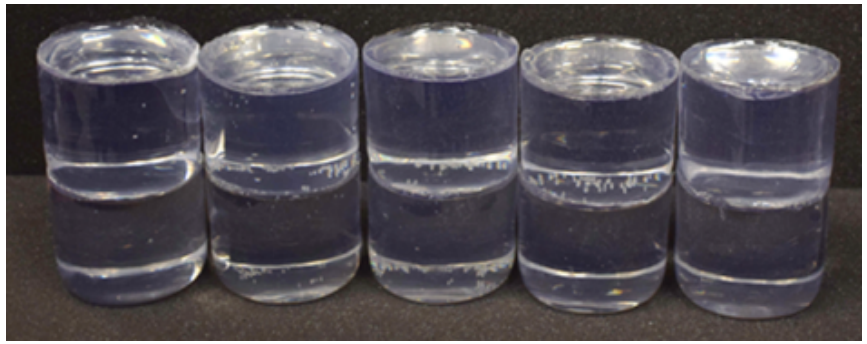
made *via* extrusion → melt-blending
(exposed to 55°C, 100 % R.H., 12 days)

5 % P2 in Styron-665 + 2 % non-fog agent

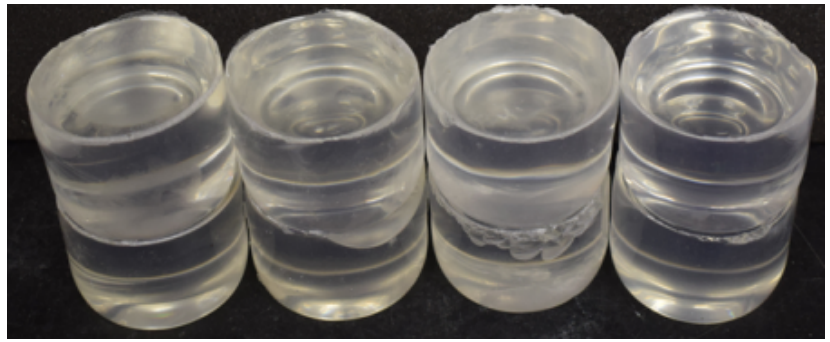


[1″ Ø x 0.5″ tall cylinders]





2 kg of 25 % DMF/PS-685D

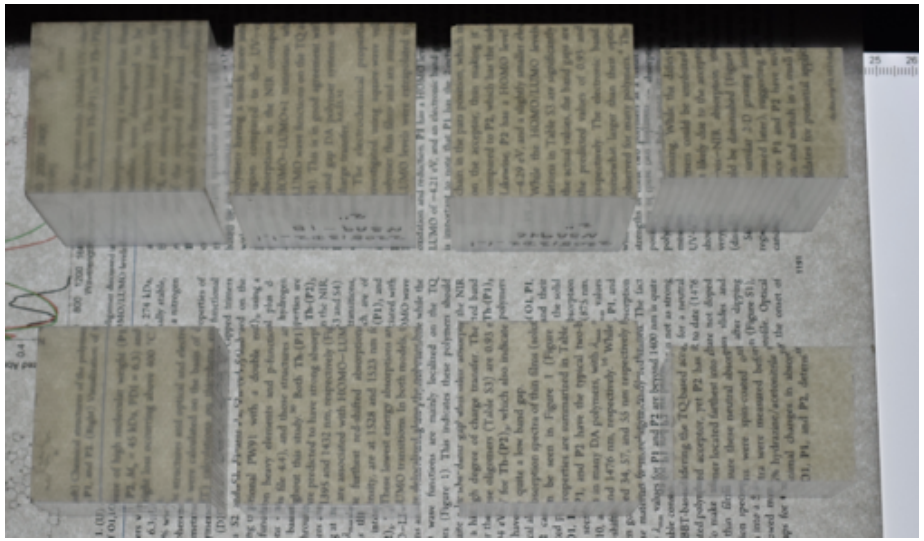


1.6 kg of 25 % DMF/POQ-66 PMMA

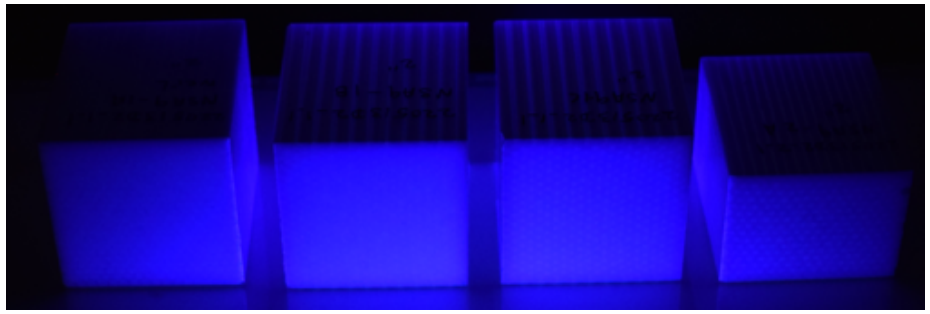
[prepared *via* direct melt-blending]

Recent Results for Scintillating Nanoguide (SNG)

30 % P2 + *in-situ* PS/ PMMA SNG specimens



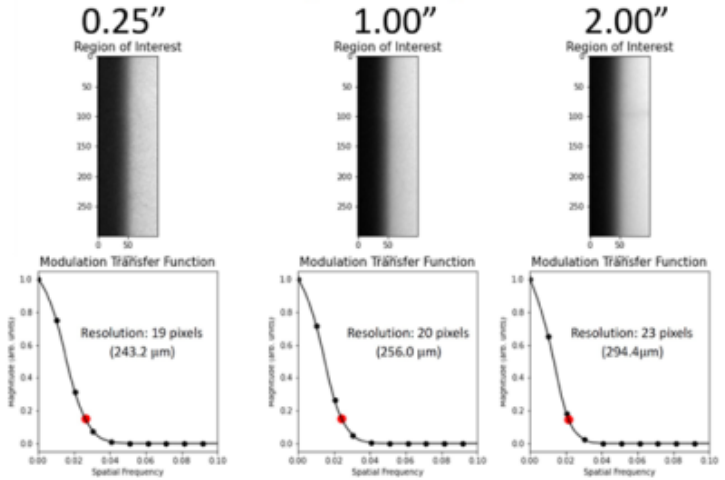
Backlit white light image



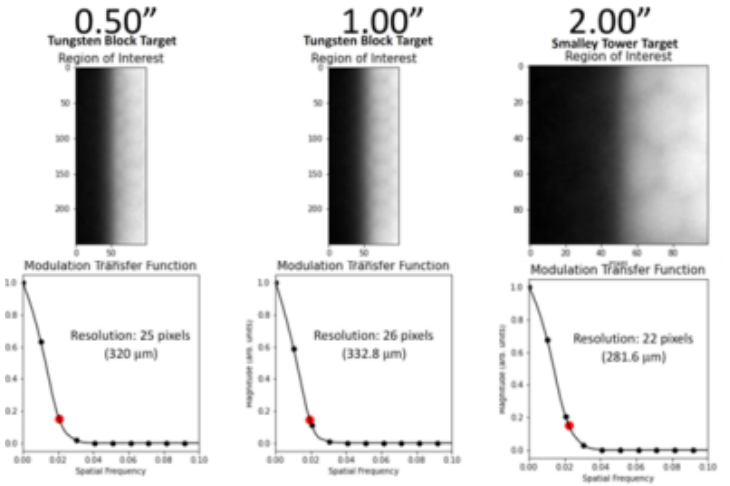
365 nm irradiation along fiber axis

29 kg of scintillator feedstock generated for SNG in 2022; SNG process and formulation optimization underway

Neutron Radiography: Bulk EJ-200 plate



Neutron Radiography: 24 % P2-in-PS/PMMA SNG



Constant spatial resolution for OGS-SNG with thickness, which bulk scintillators cannot replicate

Summary and Acknowledgements

- A scalable and low-effort production route to high light yield, PSD plastics is demonstrated
- Useful attributes of molecular OGS and OGS/polymer blends are combined
- Other fluors, polymers and additives beyond “standard” OGS/polymer are amenable
- We are melt-blending plastic scintillator at multi-kg batch scale for high-resolution neutron radiography experiments (SNG)

This work is sponsored by NNSA/NA-221
DNN R&D, Office of Proliferation Detection

National Nuclear Security Administration