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LITHIUM-LOADED PLASTIC SCINTILLATORS FOR THERMAL NEUTRON DETECTION

Plastic scintillators for thermal neutron detection

Plastic scintillators:

Boron-loaded [1 – 5] $n + {}^{10}B \longrightarrow {}^{7}Li^*(0{,}84\ MeV) + {}^{4}He(1{,}47\ MeV)$

$\qquad\qquad {}^{7}Li^* \longrightarrow {}^{7}Li + \gamma(480\ keV)$

Gadolinium-loaded Gd [7 – 10] $n + {}^{A}Gd \longrightarrow {}^{A+1}Gd + \gamma(8\ MeV)$ (for 155Gd and 157 Gd)

Cadmium-loaded [10 – 11] $n + {}^{113}Cd \longrightarrow {}^{114}Cd + \gamma(8\ MeV)$

Lithium-loaded [12 – 22] $n + {}^{6}Li \longrightarrow {}^{3}H(2{,}73\ MeV) + {}^{4}He(2{,}05\ MeV)$

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Advantages of Li-loaded plastic scintillators (Li-PS)

- ***Naturally occurring lithium*** *has an isotope* ***(^{6}Li)*** *with a high thermal neutron capture cross section, which content of up to 7.5%. Although this is not very large,* ***the enrichment of the natural mixture of lithium isotopes is not a significant problem****.*
- ***When a ^{6}Li nucleus captures a thermal neutron, ^{3}H and ^{4}He nuclei are formed****, with energies of 2.73 MeV and 2.05 MeV, respectively:*

$$n + {}^6Li \longrightarrow {}^3H(2{,}73\ MeV) + {}^4He(2{,}05\ MeV)$$

These particles are reliably detected by the scintillator material in the immediate vicinity of the capture site*, which makes it possible* ***to determine the coordinates of the event.***

- *The nuclei of lithium isotopes are about 20 times lighter than the nuclei of the isotopes of cadmium and gadolinium, which at the same mass fractions makes it possible* ***to introduce more lithium atoms into the scintillator****.*
- ***Lithium compounds are inexpensive and readily available****. Their cost, as a rule, is several times lower than the cost of cadmium and gadolinium compounds.*

Li-PS composition

Li-containing additive:

lithium acetate (CH_3COOLi) *– colorless compound, inexpensive, accessible and resistant to environmental influences.*

Scintillation fluors:

- *scintillation fluor – 2,5-diphenyloxasole –* ***PPO****.*
- *secondary scintillation fluor – 1,4-di-(5-phenyl-2-oxasolyl)benzene) –* ***POPOP****.*

This choice is due to the widespread use of these substances as components of plastic scintillators.

Polymer base:

Copolymer of ***styrene (St) with methacrylic acid (MA)*** *(molar ratio 1:0,8). At a lower concentration of polymethacrylic acid, the solubility of lithium acetate becomes too low and small systematic decrease in light yield occurs at a higher concentration.*

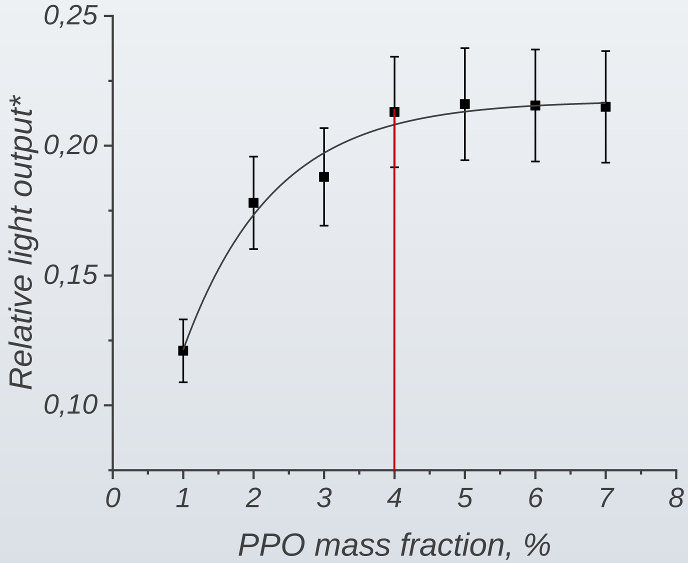
St:MA, (mole ratio)	*1:0.8*	*1:0.9*	*1:1*
Light output	*0.27 ± 0.03*	*0.23±0.03*	*0.22±0.03*

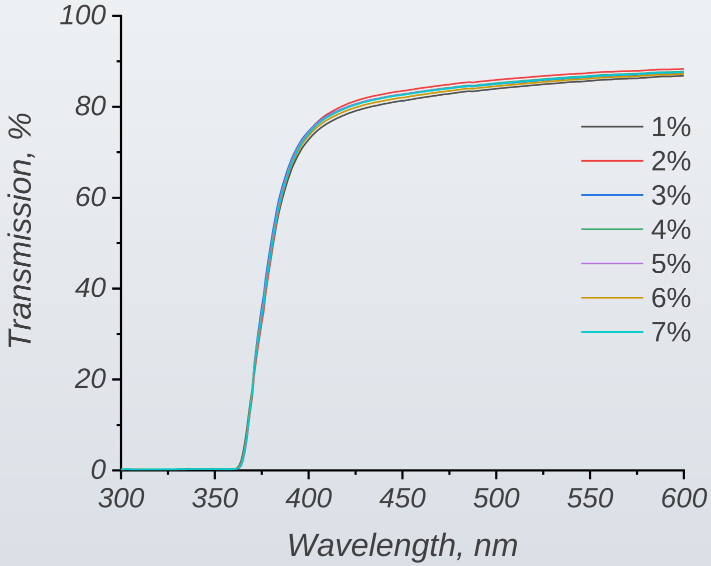
This was established by measuring the light output of Li-PS based on the selected copolymer with the following concentration of additive :

- *mass fraction of lithium (in the form of acetate) - 0.2%;*
- *mass fraction of PPO - 2%;*
- *mass fraction of POPOP - 0.0015%.*

Li-PS composition

Experimental samples of plastic scintillators: *D – 30 mm, H – 10 mm.*





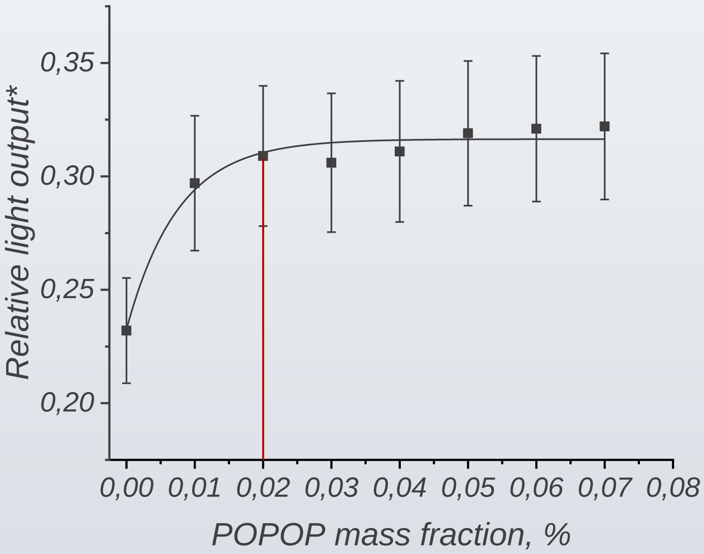
Light output of plastic scintillators based on styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with variable PPO concentration.

Transmission spectra of plastic scintillator samples based on styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with variable PPO concentration, measured relative to air.

**Relatively to: polystyrene + 2% PPO + 0,015% POPOP*

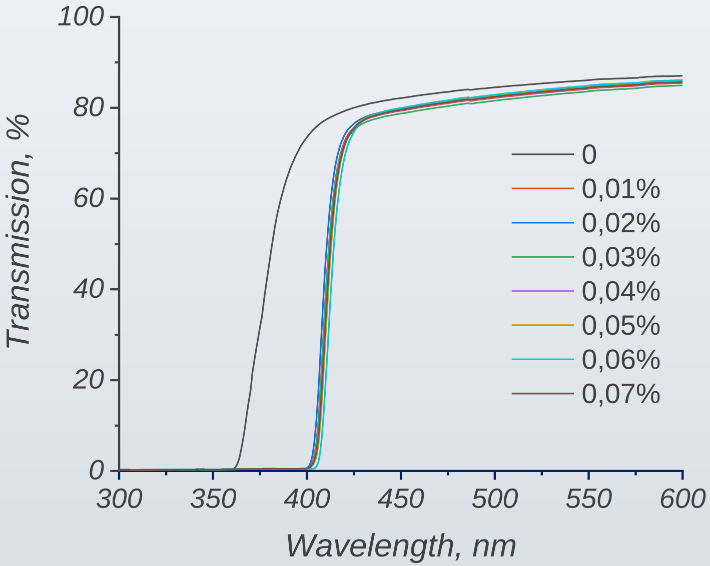
Li-PS composition

Experimental samples of plastic scintillators: *D – 30 mm, H – 10 mm.*



Light output of plastic scintillators based on styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with constant PPO concentration (4%) and variable POPOP concentration.

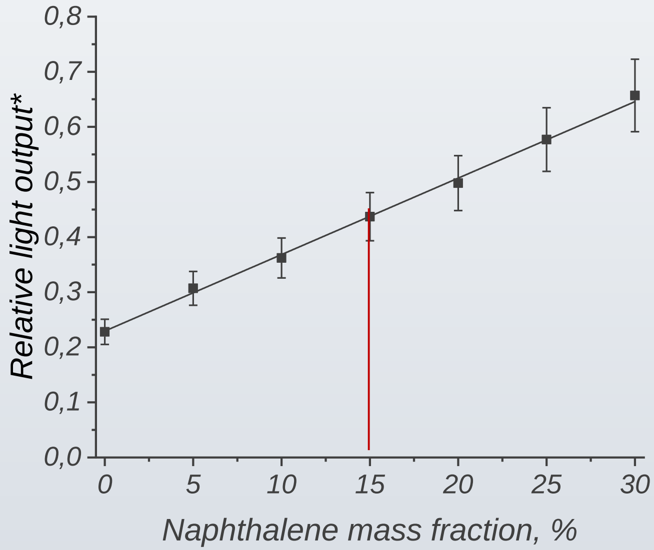
**Relatively to: polystyrene + 2% PPO + 0,015% POPOP*



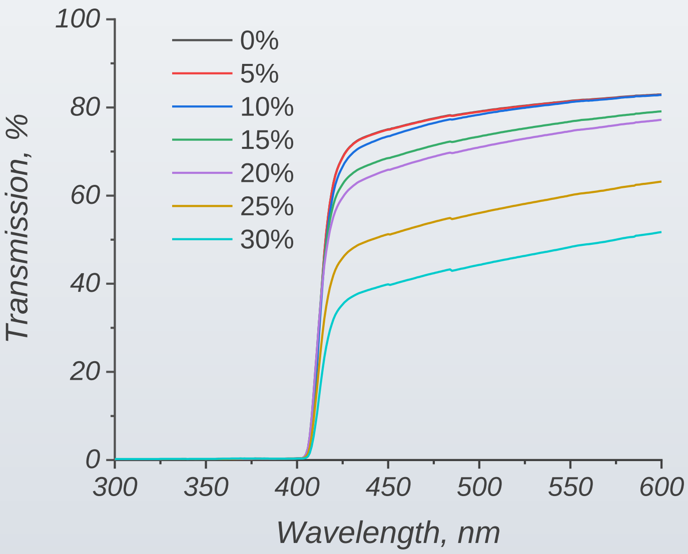
Transmission spectra of plastic scintillator samples based on styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with a constant PPO concentration (4%) and a variable POPOP concentration, measured relative to air.

Li-PS composition

Experimental samples of plastic scintillators: *D – 30 mm, H – 10 mm.*



Light output of plastic scintillators based on a styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with a constant concentration of PPO and POPOP (4% and 0.02%, respectively) and a variable concentration of naphthalene.

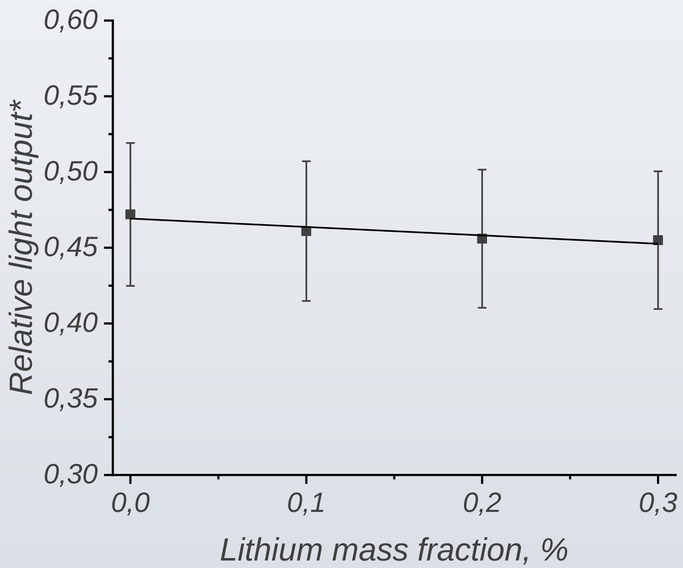


Transmission spectra of plastic scintillators based on a styrene-methacrylic acid copolymer (molar ratio 1: 0.8) with a constant concentration of PPO and POPOP (4% and 0.02% , respectively) and a variable concentration of naphthalene, measured relative to air.

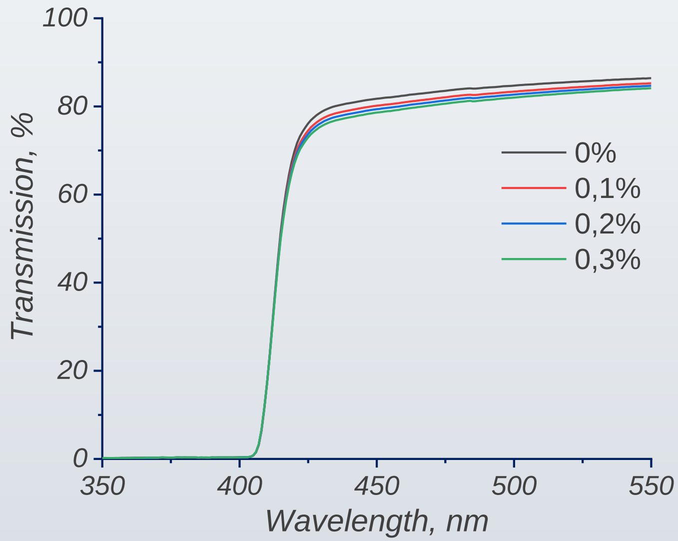
**Relatively to: polystyrene + 2% PPO + 0,015% POPOP.*

Li-PS composition

Experimental samples of plastic scintillators: *D – 30 mm, H – 10 mm.*



Light output of plastic scintillators based on a copolymer of styrene with methacrylic acid (molar ratio 1: 0.8) with a constant concentration of PPO, POPOP and naphthalene (4%, 0.02% and 15%, respectively) and a variable concentration of lithium acetate.



Transmission spectra of plastic scintillators based on a copolymer of styrene with methacrylic acid (molar ratio 1: 0.8) with a constant concentration of PPO, POPOP and naphthalene (4%, 0.02% and 15%, respectively) and a variable concentration of lithium acetate, measured relative to air.

Conclusion

1. ***The new lithium-loaded plastic scintillator*** *based on a styrene-methacrylic acid copolymer* ***was developed****.*

2. Lithium acetate *was used as a* ***element-containing additive****. This compound is colorless, readily available, and has high resistance to environmental influences.*

3. ***PPO and POPOP*** *were chosen* ***as scintillation fluors****.* ***The optimal concentrations*** *of these substances* ***were defined*** *(4% for PPO and 0.02% for POPOP).*

4. ***To increase the light yield****, a secondary solvent,* ***naphthalene****, taken in an amount of 15% (by weight)* ***was used****.*