PLASTIC SCINTILLATORS WITH THE IMPROVED RADIATION HARDNESS LEVEL.
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MOTIVATION

For the modern physical experiment it is necessary to create detectors with higher radiation resistance.

Plastic scintillator widely use for the creation of various kinds of detector systems and as a consequence there is a problem of improving the properties of the radiation resistance of a plastic scintillator.

TRADITIONAL PLASTIC SCINTILLATOR

Polymer base

PS, PV

+

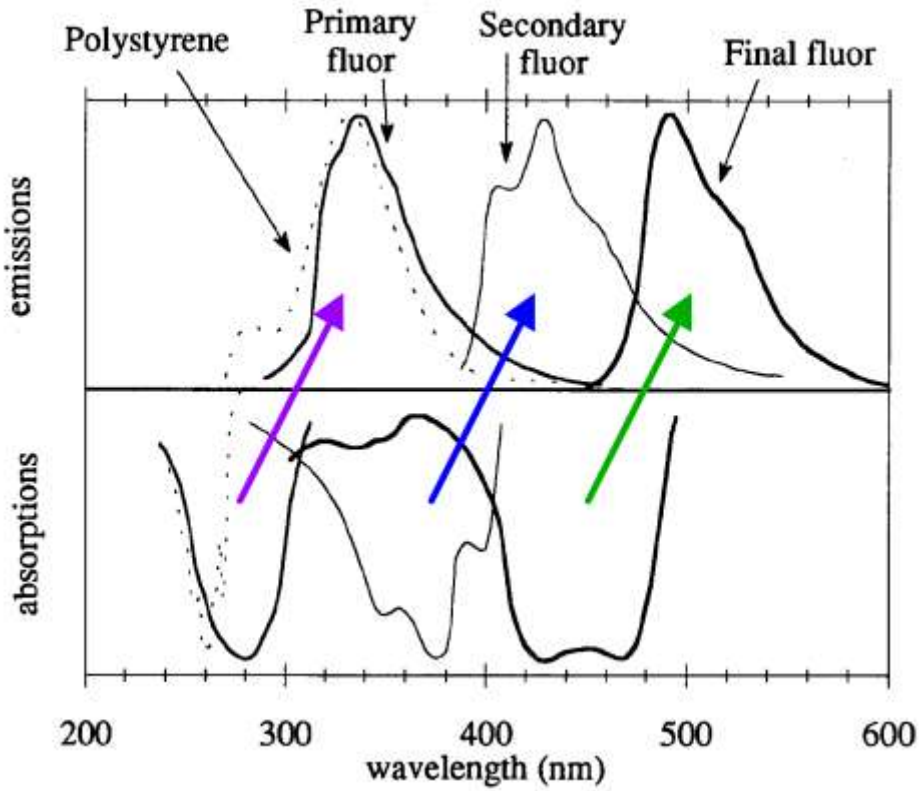
activator

P-Tph, PPO…

+

Shifter

POPOP,.. DPA…

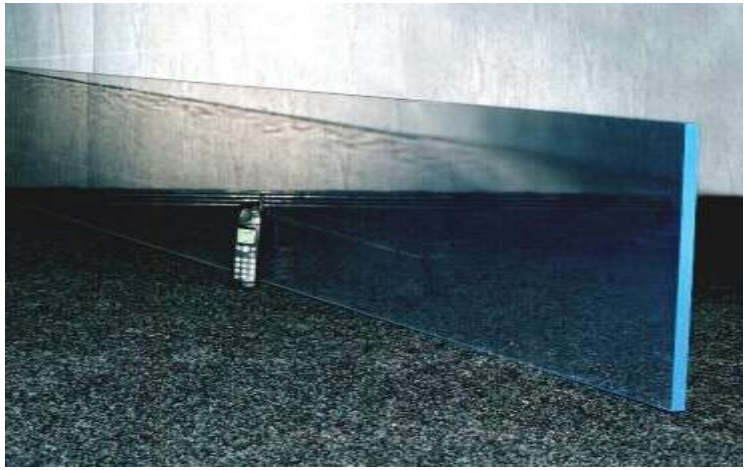


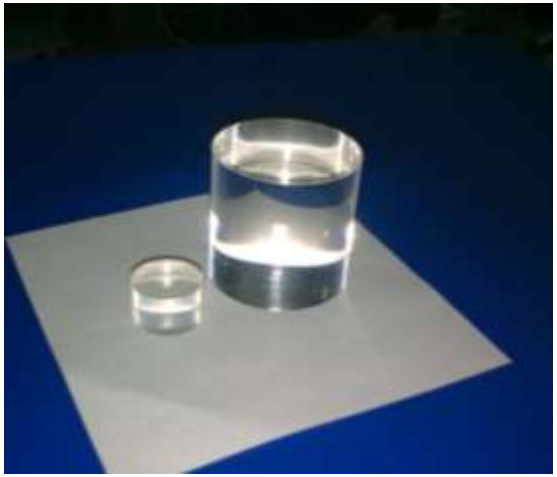
PS conditionally be presented as material consisting from Pb, Act and Sh

The optical property of fluor additives have to be correlated with matrix property to ensure the maximum rate of collection from the centers of excitation of the polymer base of the plastic scintillator.

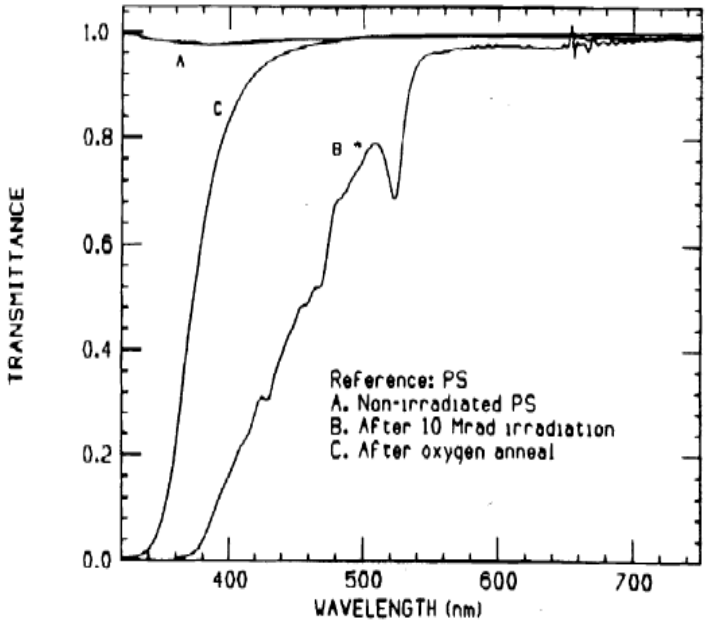
TRADITIONAL PLASTIC SCINTILLATOR

Light yield , % antracene 56
Scint, efficiency/1 MeV (e-)..... 8,600
Wavelength of Max. Emission, nm 420
No. of H Atoms per cm3, x 1022 ..... 5.13
No. of C Atoms per cm3, x 1022 ..... 4.86
No. of Electrons per cm3, x 1023 ..... 3.55
Density, g/cc: 1.08
Decay times, ns:……3
Radiation hardness, Mrad.....2

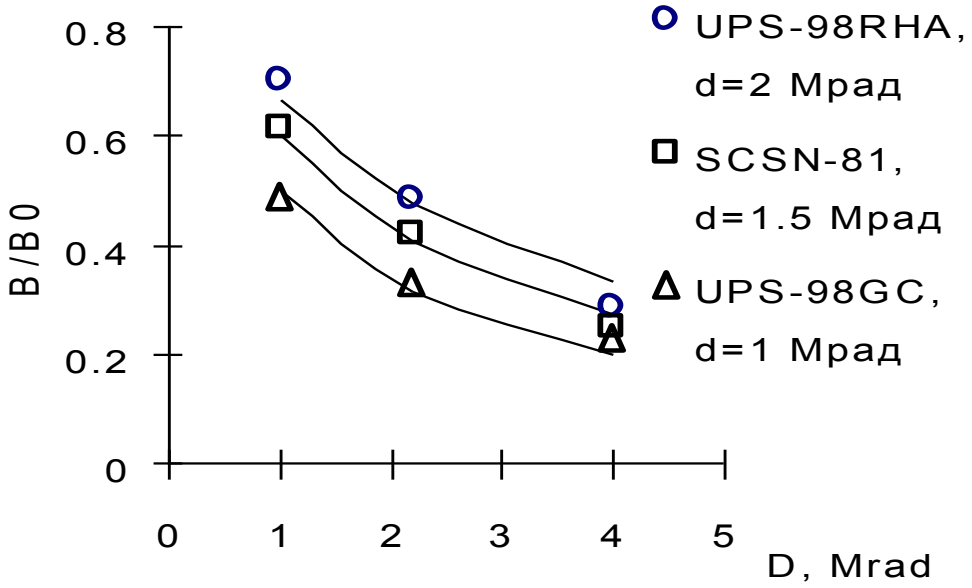




CHANGE PROPERTY OF PS UNDER IRRADIATION



Transmission spectra before and after irradiation with a dose of 10 Mrad (A.D.Bross, A.Pla-Dalmau)



Degradation of light yield under irradiation for the different PS

Under irradiation in the polymeric base of the PS the traps of optical radiation are created. it should be noted that the spectral region of their absorption coincides with the luminescence spectra of the activator.

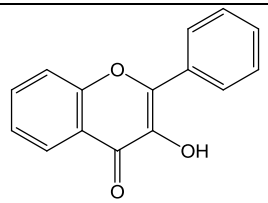
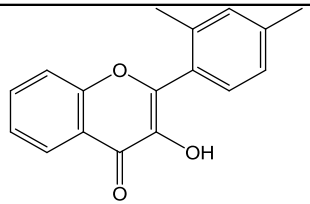
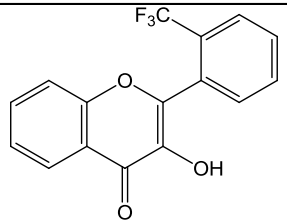
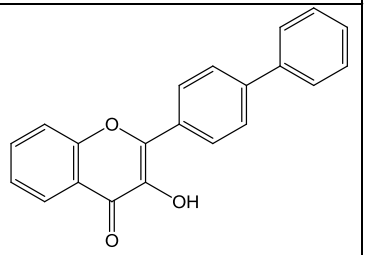
Improvement of the properties of radiation resistance can be achieved by shifting the main luminescence band to a longer wavelength range.

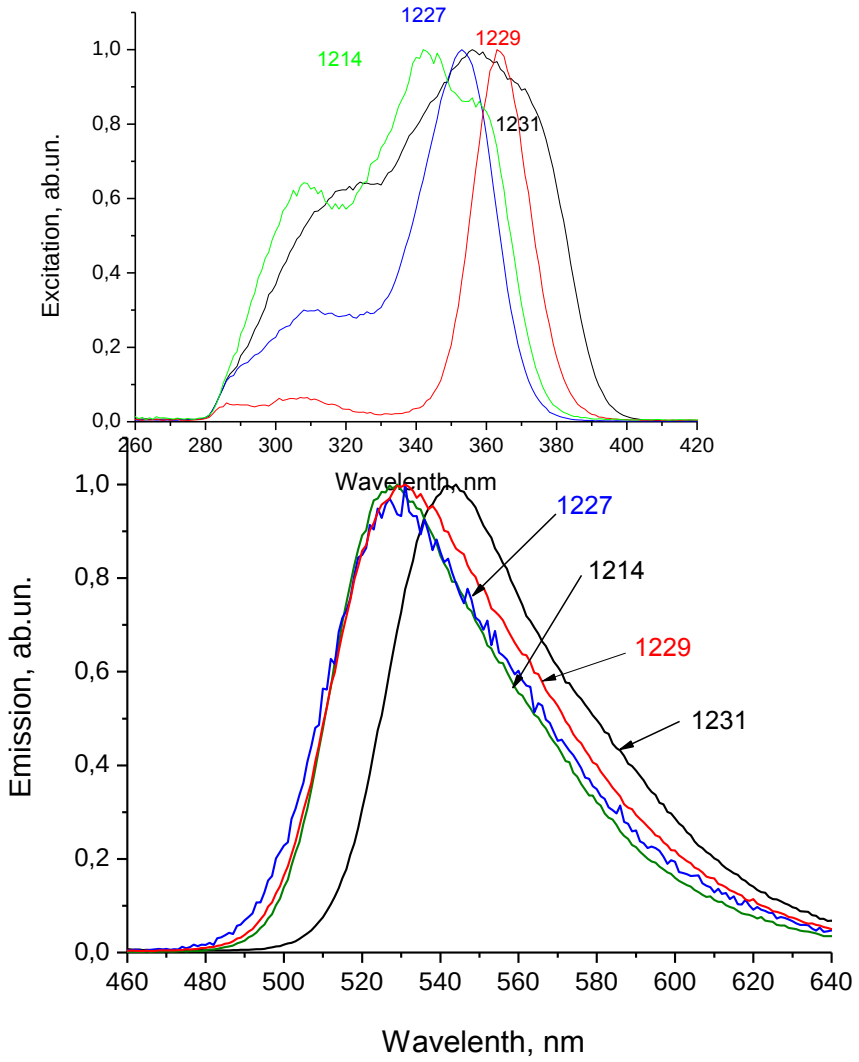
WAYS TO IMPROVE THE PROPERTIES OF RADIATION RESISTANCE

- reduction of the radicals lifetime by adding to the polymer base various kinds of diffusion amplifiers
- by shifting the main luminescence band to a longer wavelength range
- by fluorine modification of activator molecules

SHIFTING THE MAIN LUMINESCENCE BAND TO A LONGER WAVELENGTH RANGE

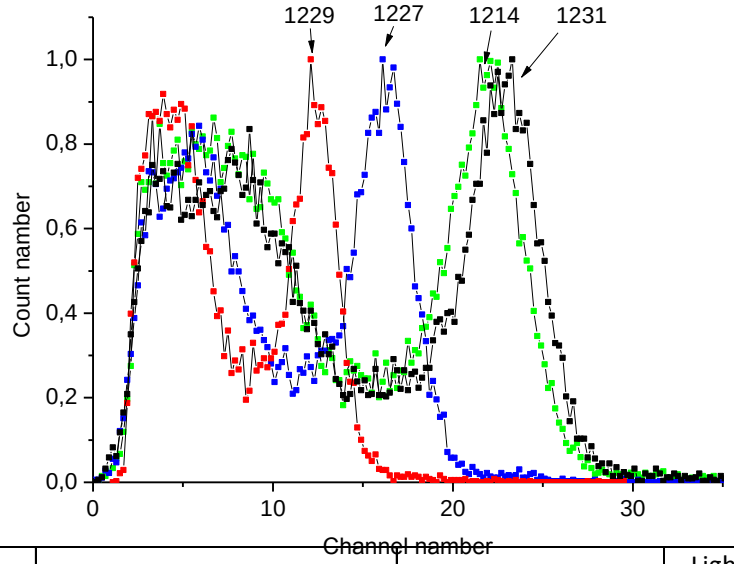
ACTIVATION PS BY 3HF MOLECULAR

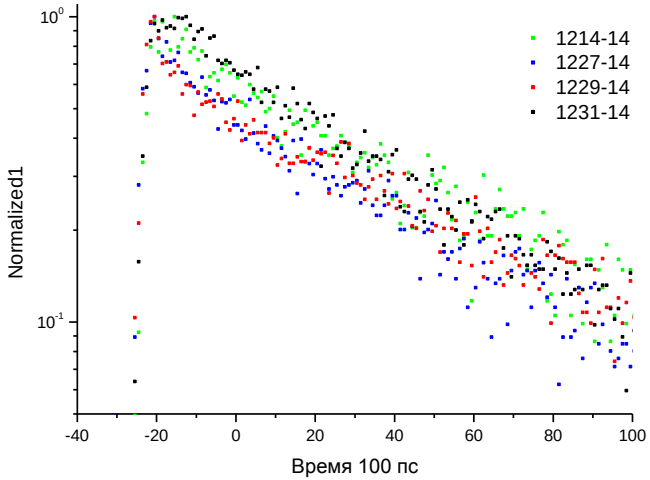
1214	
1227	
1229	
1231	



The best way to carry out the transfer of the luminescence band to the “red” region can be done with the help of 3HF molecules.

PROPERTIES OF PS, ACTIVATED BY 3HF MOLECULES



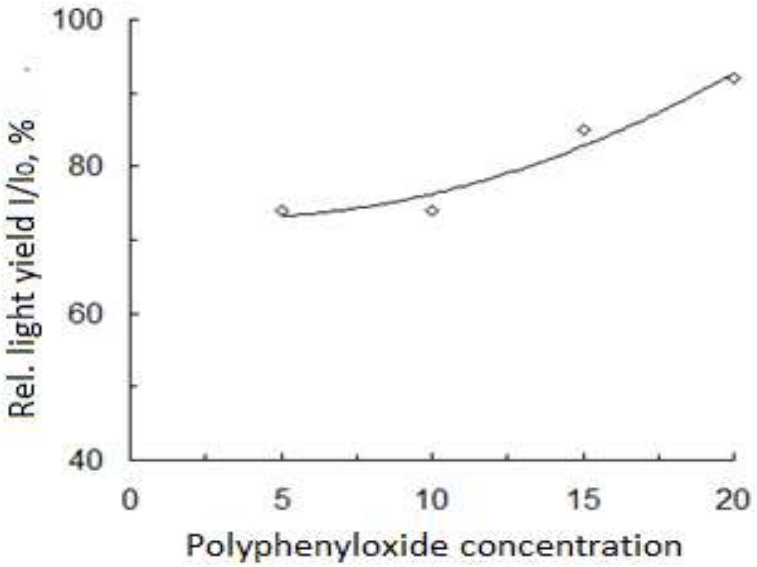


N	PS composition based on polystyrene	Light output before irradiation(L0)	Light output after irradiation with a dose3.0 Mrad (L)	L/L0, %	$D_{1.2}$ (Mrad)
1	2% 1214 (3HF)	64	47	73	7.3
2	2% 1227	52	28	53	3.6
3	2% (1229)	37	28	77	8.8
4	2% (1231)	67	53	79	9.7
5	2% p-TP + 0.05 1214	56	38	68	5.9
6	2% p-TP + 0.05% 1227	56	27	48	3.1
7	2% p-TP + 0.05% 1229	56	39	69	6.2
8	2% p-TP + 0.05% 1231	85	63	74	7.6
UPS923A	2% p-TP + 0.05% POPOP	100	47	47	3.0

Irradiation by cobalt cannon with dose rate-1.2 Krad/h

REDUCTION OF THE RADICALS LIFETIME BY ADDING TO THE POLYMER BASE VARIOUS KINDS OF DIFFUSION AMPLIFIERS

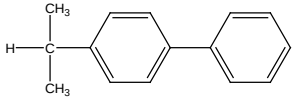
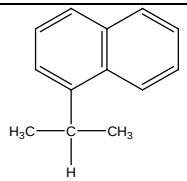
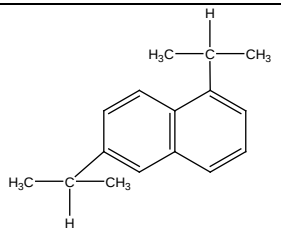
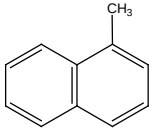
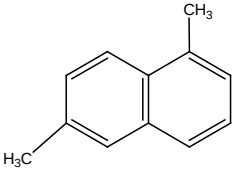
INCREASED MOBILITY OF RADICALS.



The dependence of the light output of PS I / I on the concentration of polyphenyl oxide (the diffusion amplifier in polystyrene) at the radiation dose of 2,8 Mrad.

The introduction of diffusion amplifiers into the polymer base of a PS can lead to an increase in its radiation hardness.

BASIC PLASTICIZERS OF POLYMER BASE

Plasticizer	Structural formula	Gross formula	T_{bol}, °C	T_{melt}, °C
4-Isopropylbiphenyl (IPBP)		$C_{15}H_{16}$	345	+11
1-Isopropylnaphthalene (IPN)		$C_{13}H_{14}$	-	-16
1,6-Diisopropylnaphthalene (1,6DIPN)		$C_{16}H_{20}$	306	-
1-Methylnaphthalene (1MN)		$C_{11}H_{10}$	244	-30
1,6-Dimethylnaphthalene (1,6DMN)		$C_{12}H_{12}$	264	-17

The addition to the polymer base of PS leads to a considerable degradation of the mechanical properties of the polymer.
Material becomes soft.
To restore the mechanical properties PS, it is necessary to crosslink the polymer base.

PROPERTIES OF CROSSLINKED PS WITH DIFFUSION ENHANCERS AND ACTIVATED BY 3HFMOLECULES (530NM)

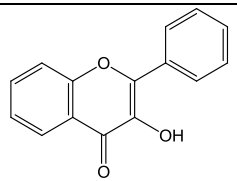
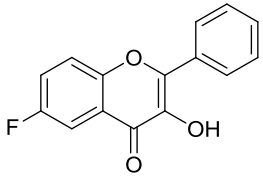
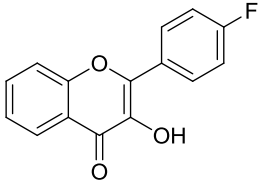
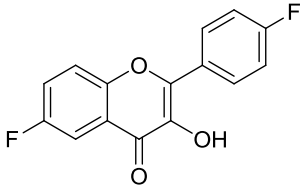
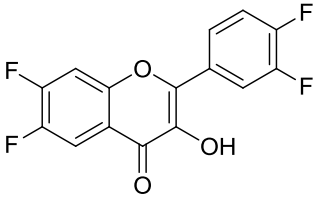
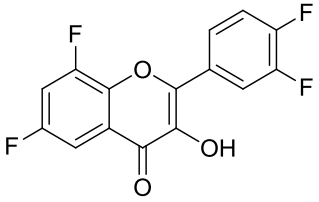
№ образца ПС	Усилитель диффузии	Cross-linking agent	Primary luminescent dopant	Secondary luminescent dopant	HV, MPa	L0, % (D = 0 Mrad)	L, % (D = 3.3 Mrad)	L/L0, %	D1/2, Mrad
1452	–	–	2% 3HF	–	122	64	49	76	8,3
1456	–	–	2%BP-3HF	–	121	68	55	81	10,9
1457	–	–	2% F-3HF	–	120	68	52	77	8,8
1458	25%IPDP	8%DVDP	1,5% BP-3HF	–	148	66	57	87	16,4
1459	25%IPDP	8%DVDP	1,5% F-3HF	–	147	60	56	94	37,0
1460	25%IPDP	8%DVDP	2%p-TP	0,1%BP-3HF	149	63	38	61	4,6
1461	25%IPDP	8%DVDP	2%p-TP	0,1% F-3HF	148	55	34	62	4,8
1462	25%IPDP	8%DVDP	2%p-TP	0,1%POPOP	147	51	33	65	5,3
UPS923A	–	–	2%p-TP	0,1%POPOP	122	100	51	51	3.0

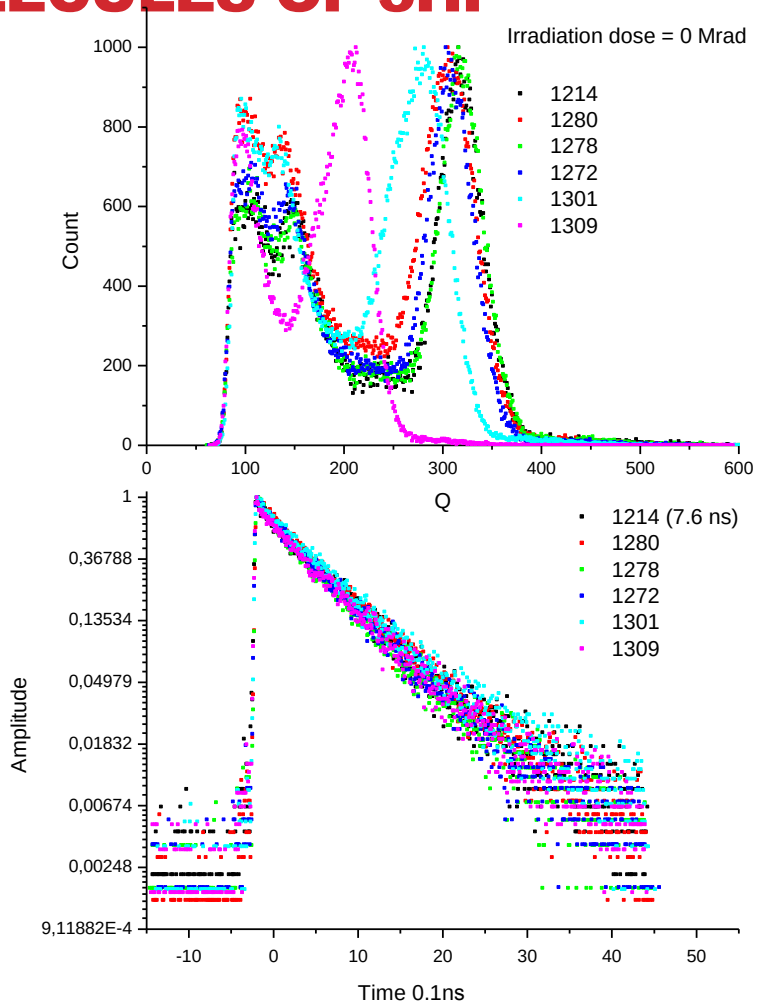
A PS with a half-attenuation dose exceeding 20 MPa was found.

But to realize this approach to the production of large-sized plastic is not possible now.

FLUORINE MODIFICATION OF ACTIVATOR MOLECULES

PS WITH FLUORINE MODIFIED MOLECULES OF 3HF

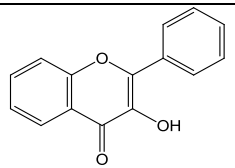
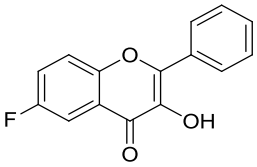
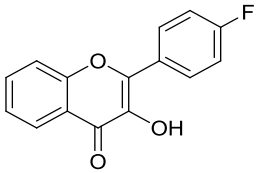
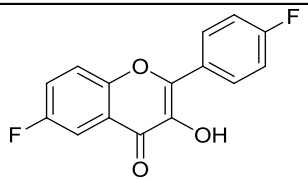
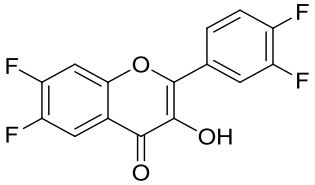
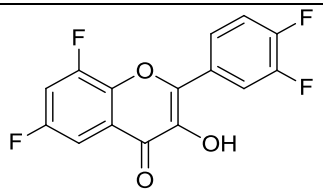
1214	
1278	
1272	
1280	
1301	
1309	



Under of irradiation, degradation occurs not only in the polymer base but also in the activator molecules. It is generally known that fluorination leads to an increase in the photostability of dye molecules.

Molecules 3HF with different levels of replacement of hydrogen atoms by fluorine atoms were synthesized.

RADIATION HARDNESS PS ACTIVATED BY FLUORINE MODIFIED 3HF MOLECULES

1214	
1278	
1272	
1280	
1301	
1309	

Irradiation produced by cobalt cannon with dose rate-1.2 Krad/h

	1214	1280	1278	1272	1301	1309
D1/2	7,6	15,7	14,3	14,5	20,6	21,2

With new activators the radiation hardness in 20Mrad was reached.

It should be noted that this method is applicable to the creation of technology for the production of large-sized plastic.

CONCLUSION

The compositions of PS that are able to resist irradiation with a dose load exceeding 20 Mrad are determined.