POLYMER SCINTILLATOR PRODUCTION USING BULK POLYMERIZATION METHOD

Łukasz Kapłon

dr Andrzej Kochanowski, dr Marcin Molenda, Anna Wieczorek

Department of Chemical Technology
Faculty of Chemistry
Jagiellonian University

21.09.2013

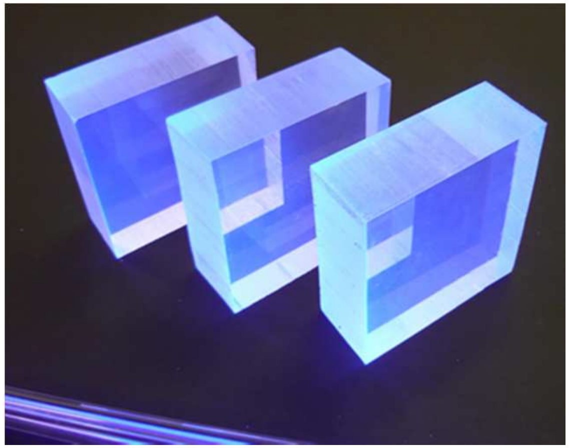
Research objectives

1) **optimization of synthesis conditions**:

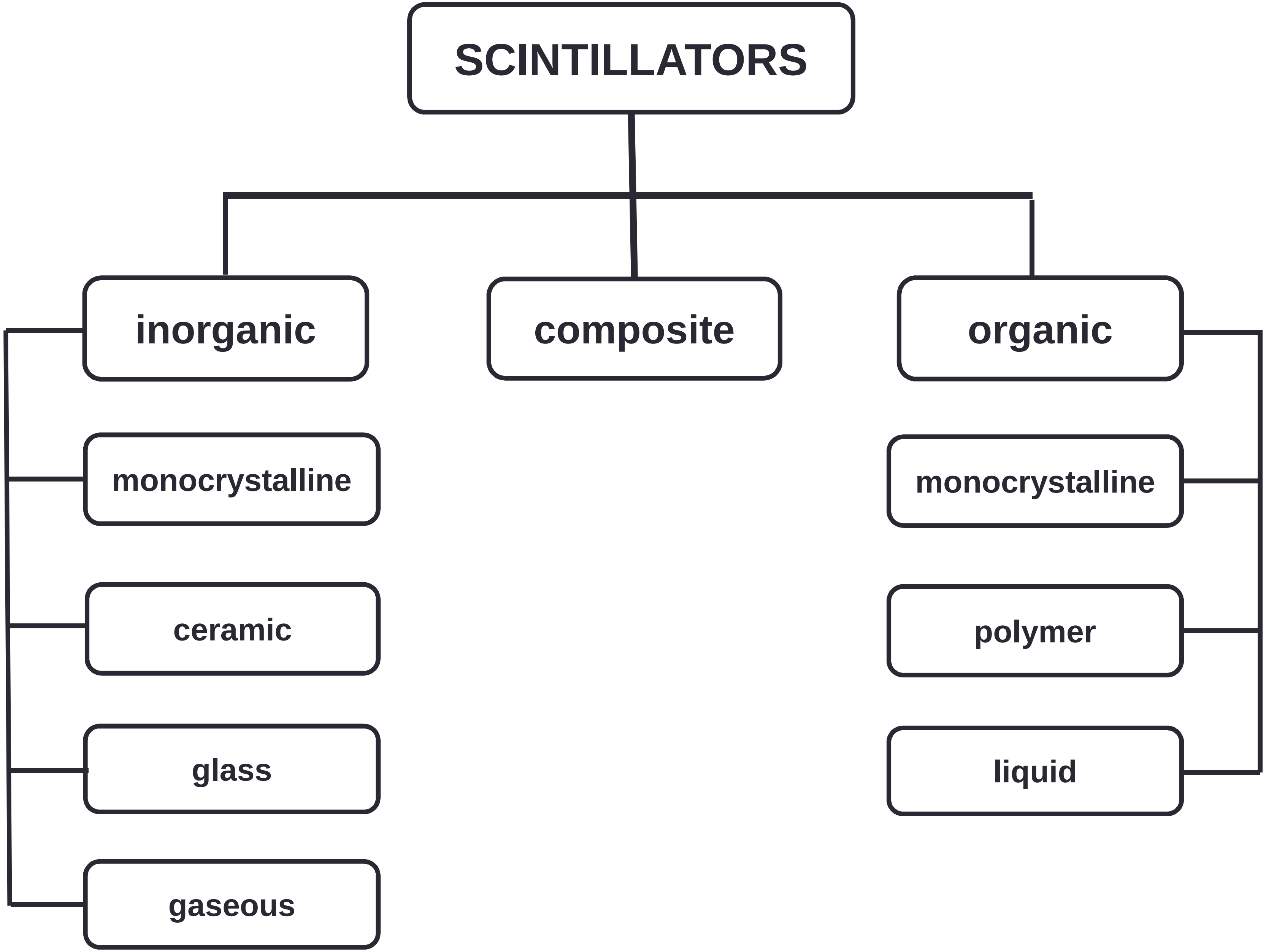
- manufacturing of scintillators without optical defects;
- increase of polymerization yield - ensuring of maximum conversion from monomer to polymer;
- obtaining polymer with high average molecular weight.

2) **improvement scintillators properties for PET detectors application**:

- increase of light output;
- decrease of decay time;
- matching of emission spectra of the polymer scintillator to quantum efficiency of PMT.



Types of scintillators



Characteristics of polymer scintillators

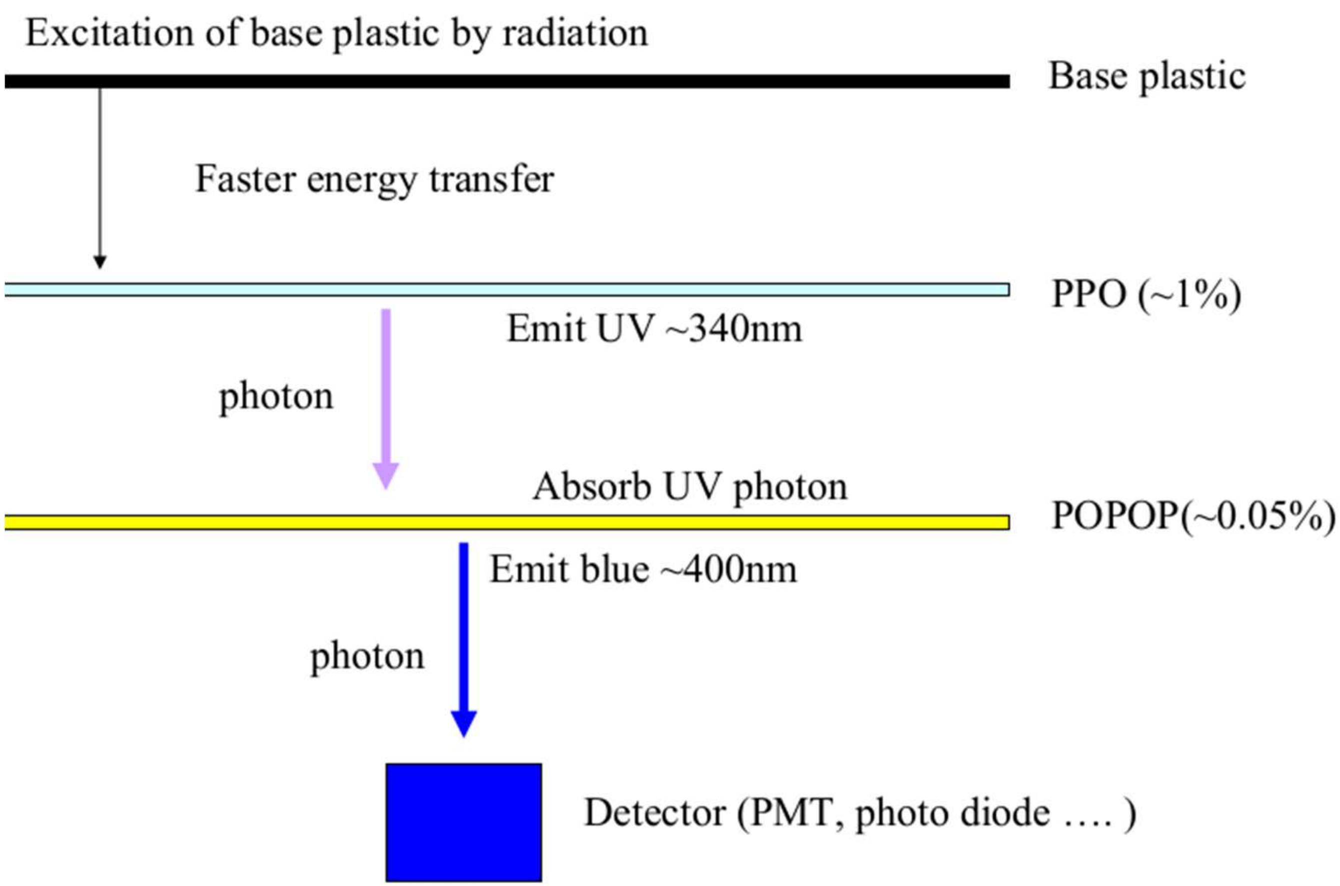
advantages

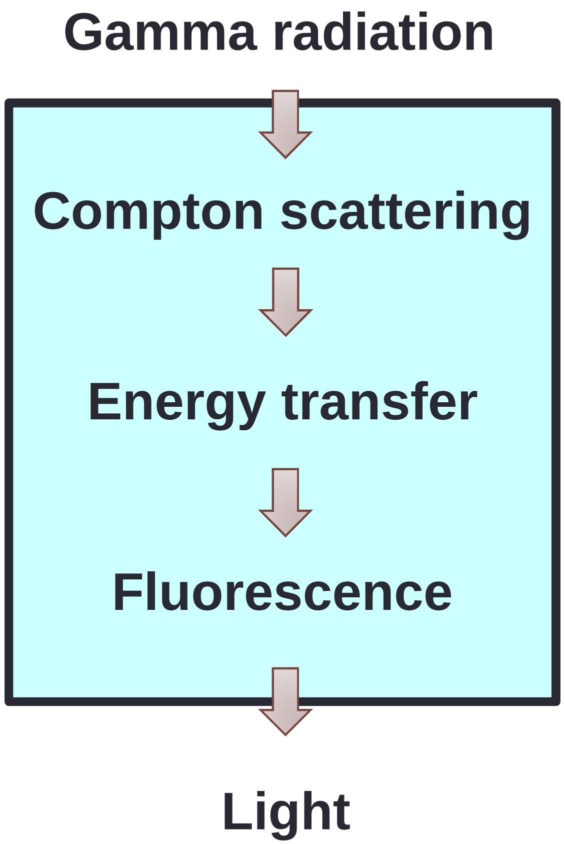
- short decay time < 5 ns
- high transparency for emitted light
- low cost of production ~ 100 $/kg
- possibility to produce large-size plates or rods > 100 kg
- ease of mechanical processing and ability to obtain different shapes (casting-like process)

drawbacks

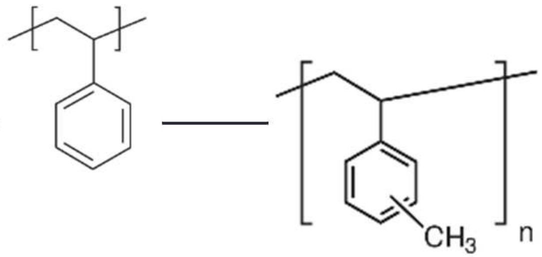
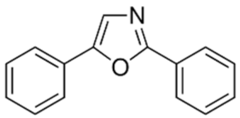
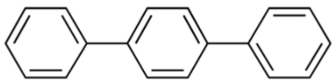
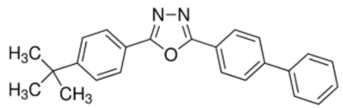
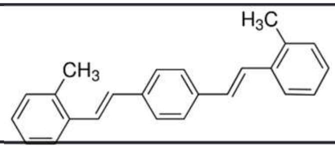
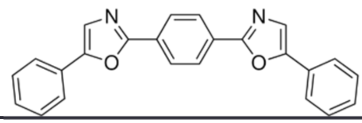
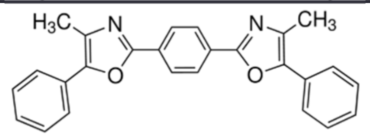
- low effective atomic number Z_{eff} ~ 6
- moderate light output ~ 10 000 photons/MeV of absorbed radiation
- surface vulnerable to mechanical damage (scratch)
- softening point ~ 70°C

Plastic scintillators - principle of operation



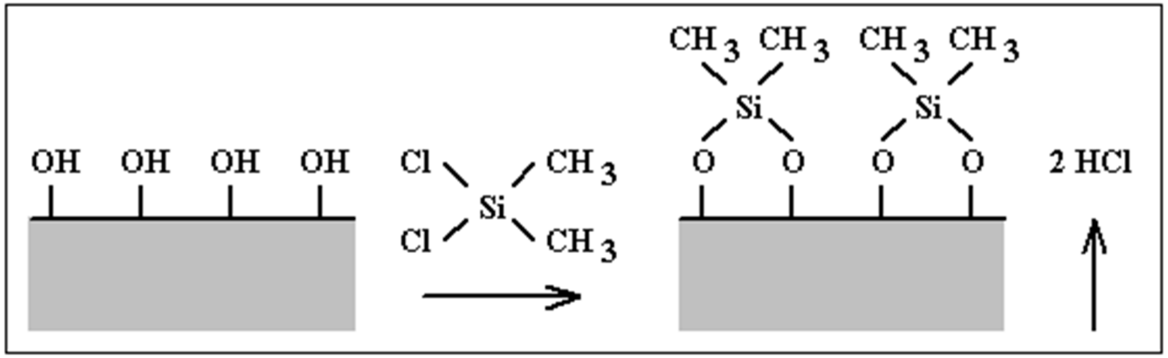


Chemical composition

Common name	Chemical formula	Function
polystyrene		polymer base
polyvinyltoluene		
PPO		1st fluorescent additive ~ 2%
p-terphenyl		
butyl-PBD		
bis-MSB		2nd fluorescent additive: wavelength shifter ~ 0,02%
POPOP		
dimethyl-POPOP		

Synthesis stages

glass ampoule preparation
- glass surface treatment -
silanization



removal of inhibitor and impurities from monomer – adsorption on activated alumina sorbent

dissolution of fluorescent compunds in monomer
&
vacuum degassing
of the resulting solution

Synthesis stages II

sealing of glass ampoules under vacuum

⇩

multi-step
bulk polymerization
in furnace

⇩

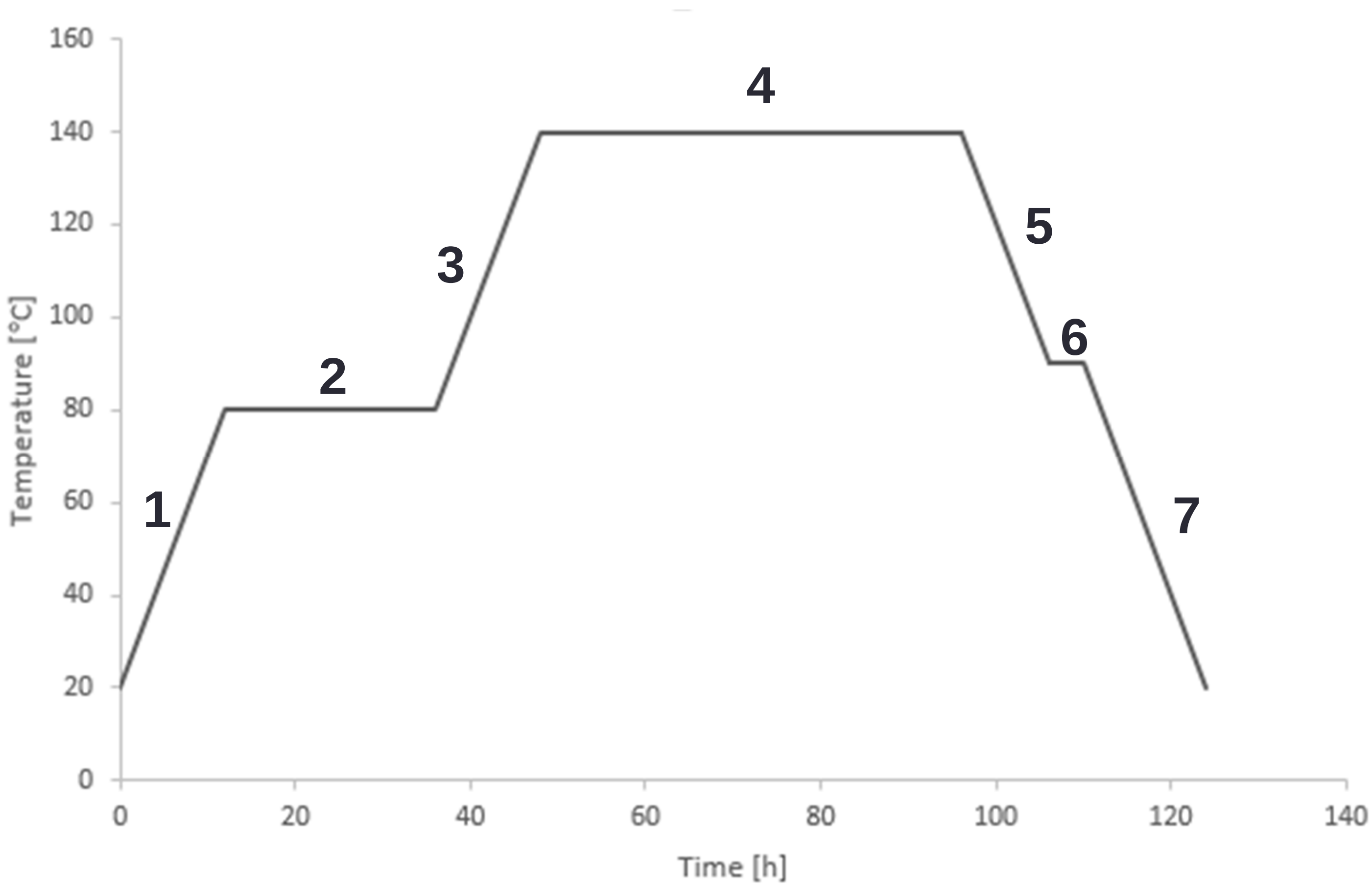
breaking ampoules;
cutting, polishing

New furnace

New special tube furnace – main features

- automatic and autonomic control of the process parameters (temperature, time, heating/cooling rate);
- programing from PC;
- *on-line* saving to PC of process temperature profile for each zone (thermal history);
- 4 heating zones;
- 7 steps per cycle;
- temperature up to 260°C.

Temperature cycle



1 – heating I
2 – prepolymerization
3 – heating II
4 – polymerization
5 – cooling I
6 – annealing
7 – cooling II

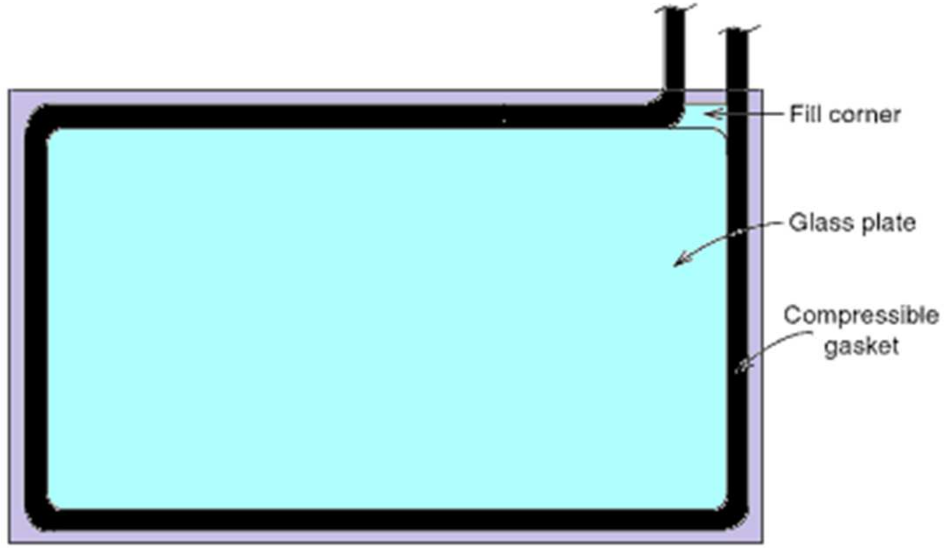
Technical problems

issue	photo	solution
yellowing of the upper part of sample		sealing of glass ampoules under vacuum or filling with nitrogen
cracking of samples		annealing of the polymer between cooling stages
defects and cracks on surface		selection of appropriate comonomers
bubbles in the samples volume		optimization of temperature program cycle (rate of polymerization)

Industrial production – batch cell bulk polymerization

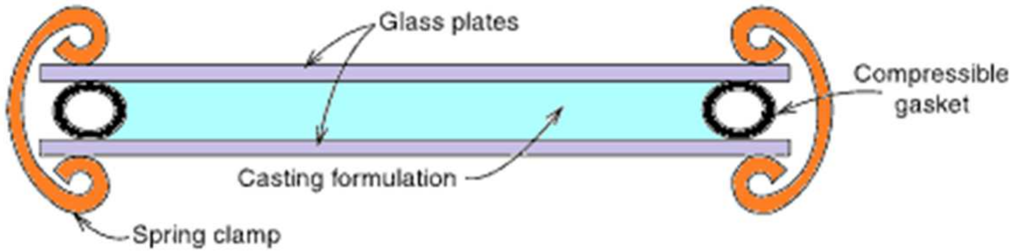
Casting into a mold and bulk polymerization

1) purification of the monomer
2) dissolving additives
3) degassing
4) mold preparation
5) pouring the solution into a mold
6) polymerization in an oven
7) annealing of the polymer block
8) mechanical processing



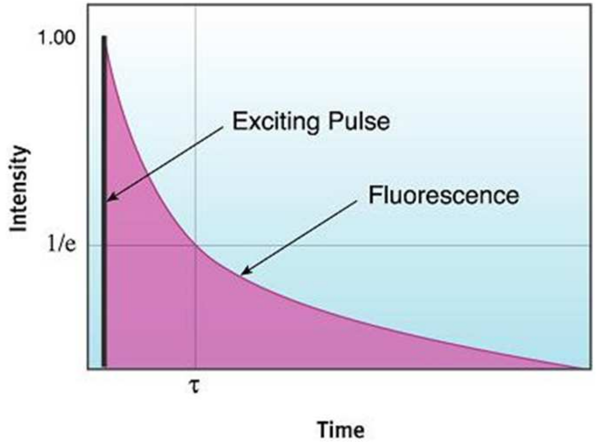
Advantages:

- ✓ high product transparency to visible light;
- ✓ no optical defects and impurities;
- ✓ ability to produce large-sized scintillators of different shapes



Measurement the properties of plastic scintillators

- light output decay time



- wavelength of maximum emission

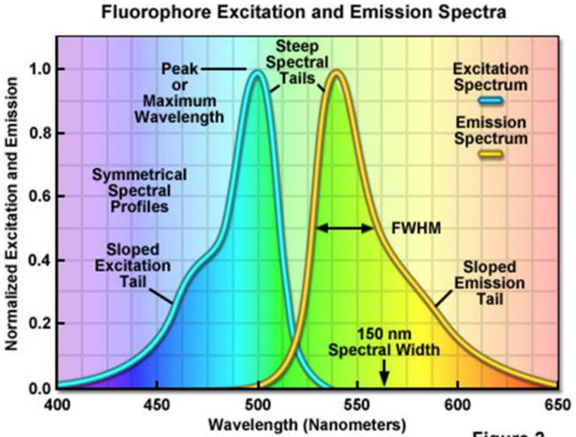
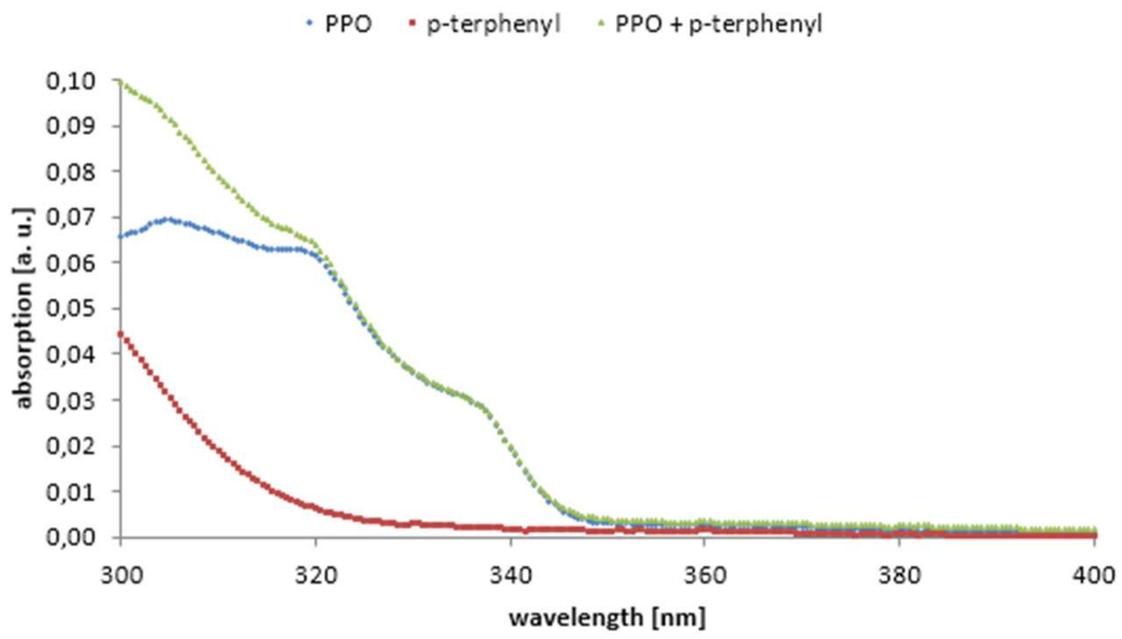
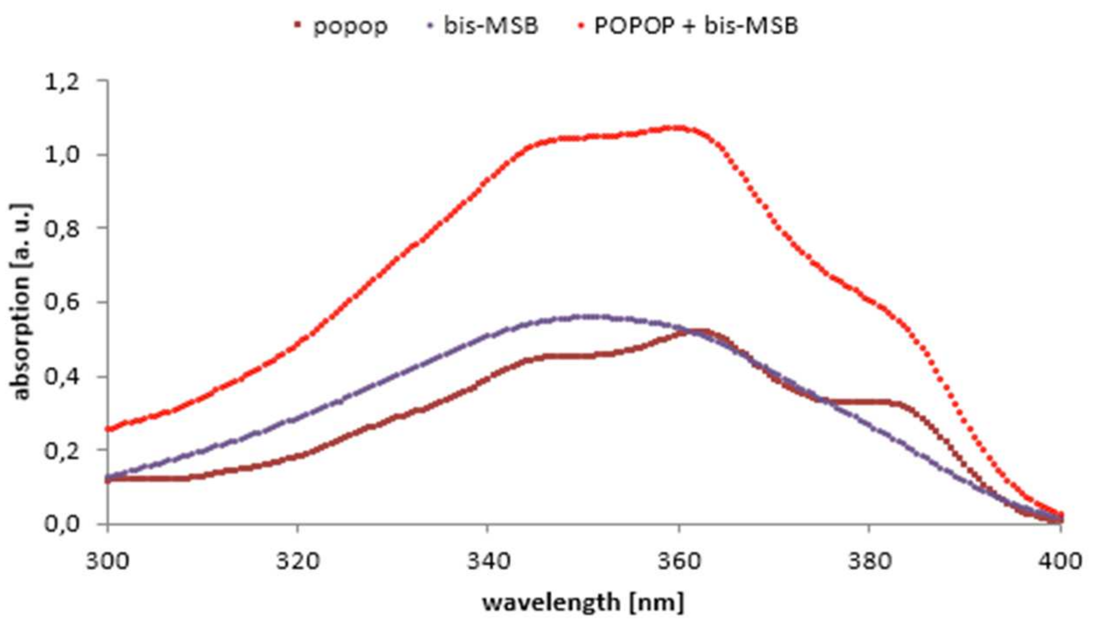


Figure 2

Absorption spectra in solution

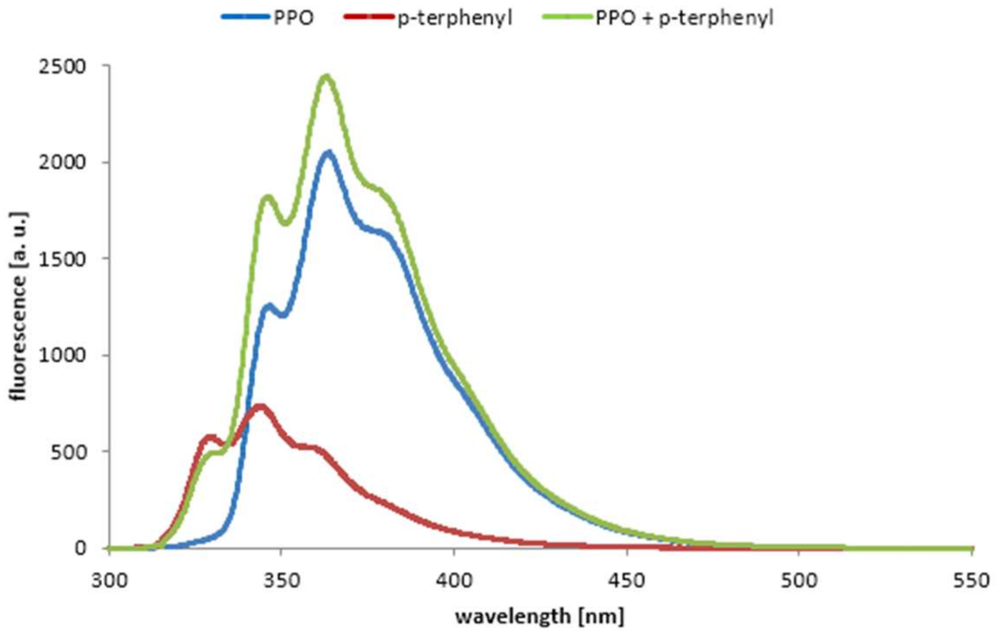


1st fluorescent additives

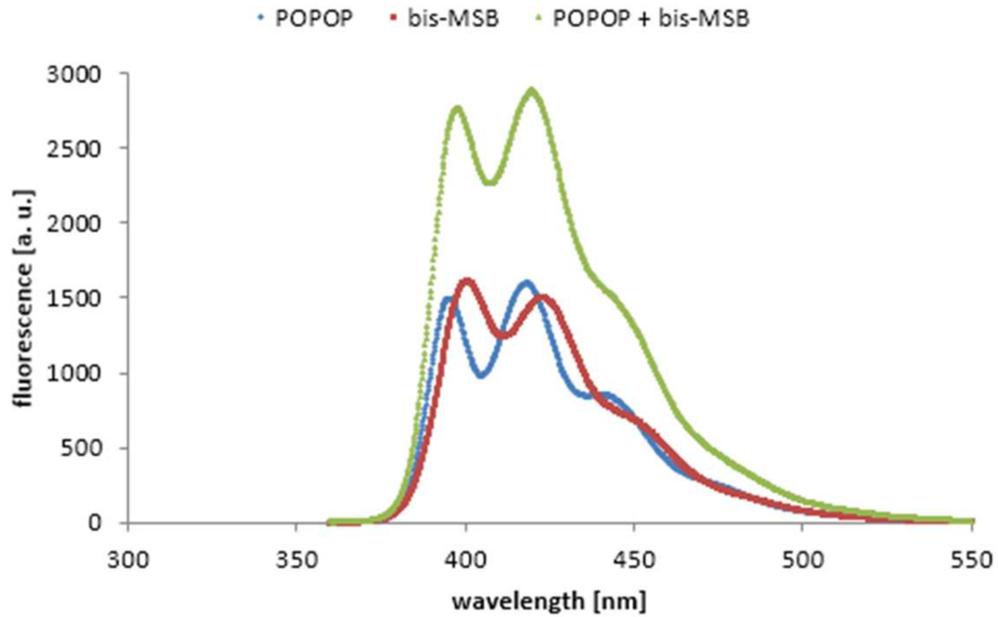


wavelength shifters

Fluorescence spectra in solution



1st fluorescent additives

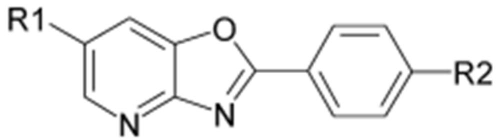


wavelength shifters

Cooperation with other scientific groups

- Femtochemistry Group, Faculty of Chemistry, Jagiellonian University

- Department of Chemistry, University of Agriculture



- Coordination and Bioinorganic Physicochemistry Group, Jagiellonian University

Current research and plans for the future

- measuring absorption and emission spectra of fluorescence compounds in solution and in polymer;
- examination of influence of crosslinking monomer to scintillators optical and mechanical properties;
- first attempt of manufacturing of long rod scintillator;
- measuring fluorescence decay time and testing new fluorescence phosphors
- making composite scintillators from polymer and fluorescent semiconductors on the scintillators surface.

Conclusions

- use antiadhesive layer that prevents sticking polymer to glass;
- elimination of optical defects through appropriate polymerization conditions;
- achieve of 99% conversion from monomer to polymer;
- optimal temperature range of the process 120-140°C;
- time of the process manufacturing about 5 days.

Thank you!