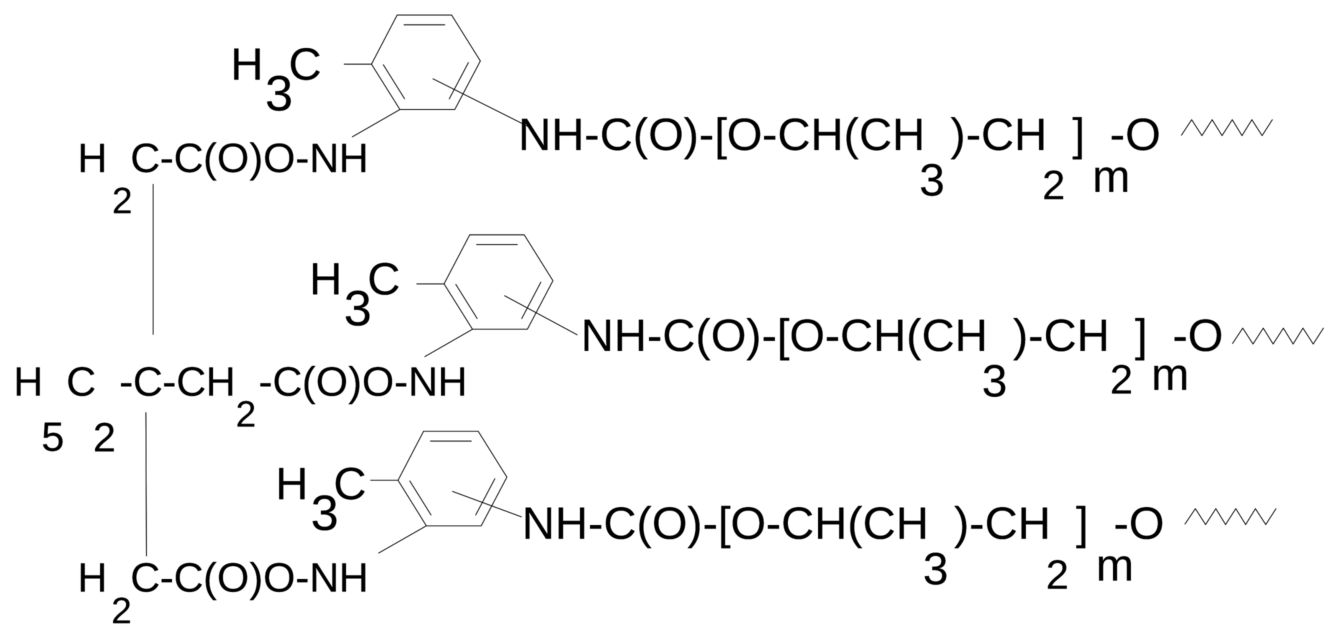
Polyurethane matrices for the solid-state elements in dye lasers

L. Kosyanchuk[1], V. Bezrodnyi[2], N. Babkina[1], N. Kozak[1], T. Bezrodna[2], O. Antonenko[1]

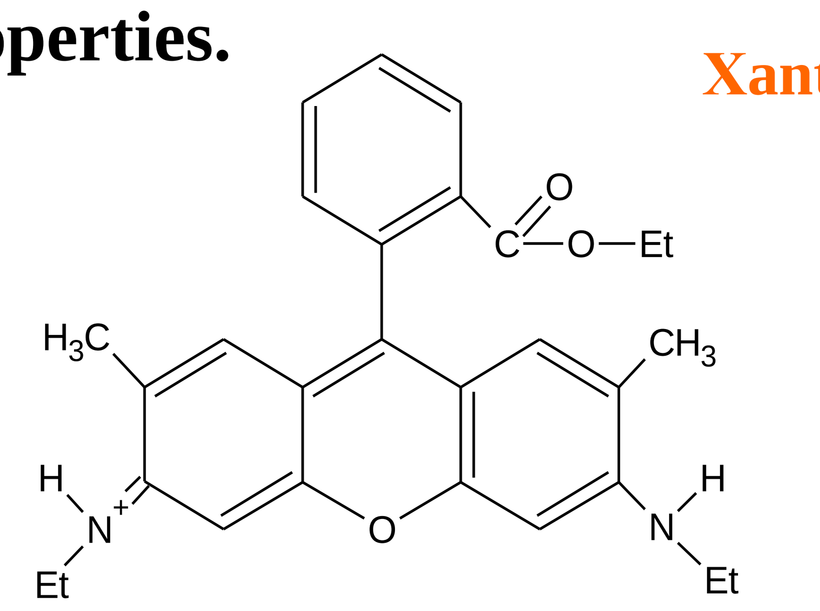
[1]Institute of Macromolecular Chemistry NAS of Ukraine, 48 Kharkivske av., Kyiv 02160, Ukraine
[2]Institute of Physics NAS of Ukraine, 46 Nauki av., Kyiv 03028, Ukraine

Among the transparent polymers used for developing solid-state elements for the dye lasers, the polyurethanes (PU) are of a special interest. Mild conditions of their preparation provide prevention of the decomposition for the dye molecules. Moreover, since the PU are mainly flexible polymers, these materials turn out to possess satisfactory radiation resistance. They are also good solvents for most dyes of different classes. One of the main reasons for the worsening of the spectral-luminescent characteristics of the laser active media (both liquid and solid-state) is associates of dye molecules. The aim of this work is to study the mutual effects of the PU matrices and included dyes, in particular, the dye photostability and spectral properties.

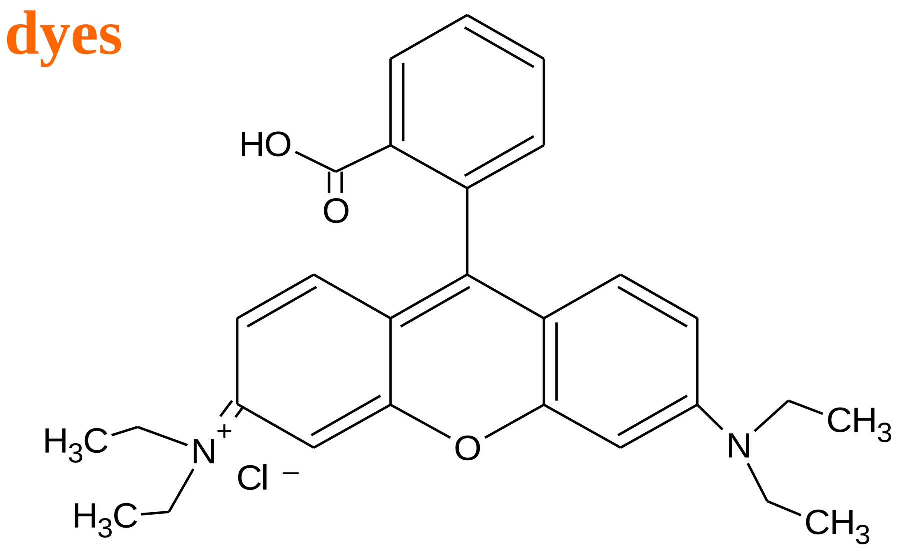


PU (polypropylene glycol MM 1000, toluene diisocyanate, trimethylolpropane)

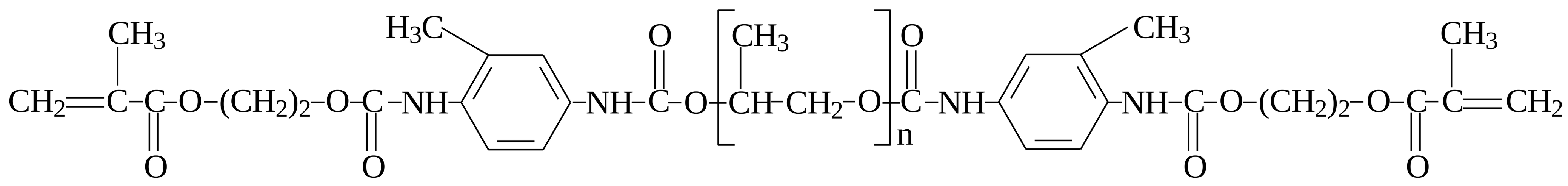
Xanthene dyes



Rhodamine 6G (R6G)



Rhodamine B (RB)



Oligourethane acrylate (polypropylene glycol, toluene diisocyanate, 2-hydroxyethyl methacrylate) (OUA)

Comparison matrix, polyurethane acrylate (PUA), was obtained by radical polymerization of OUA

The PU estimated polarity parameter, which determines the level of specific intermolecular interactions between dye chromophores and polar groups of polymers, is found out to be higher than this value for the PUA. The increasing of the polymer polarity causes specific solvation of dye molecules by the PU polar groups, which prevents the dye association. This is confirmed by the absorption spectra of dyes and their improved photostability in the PU under irradiation by an ultrahigh-pressure mercury lamp.

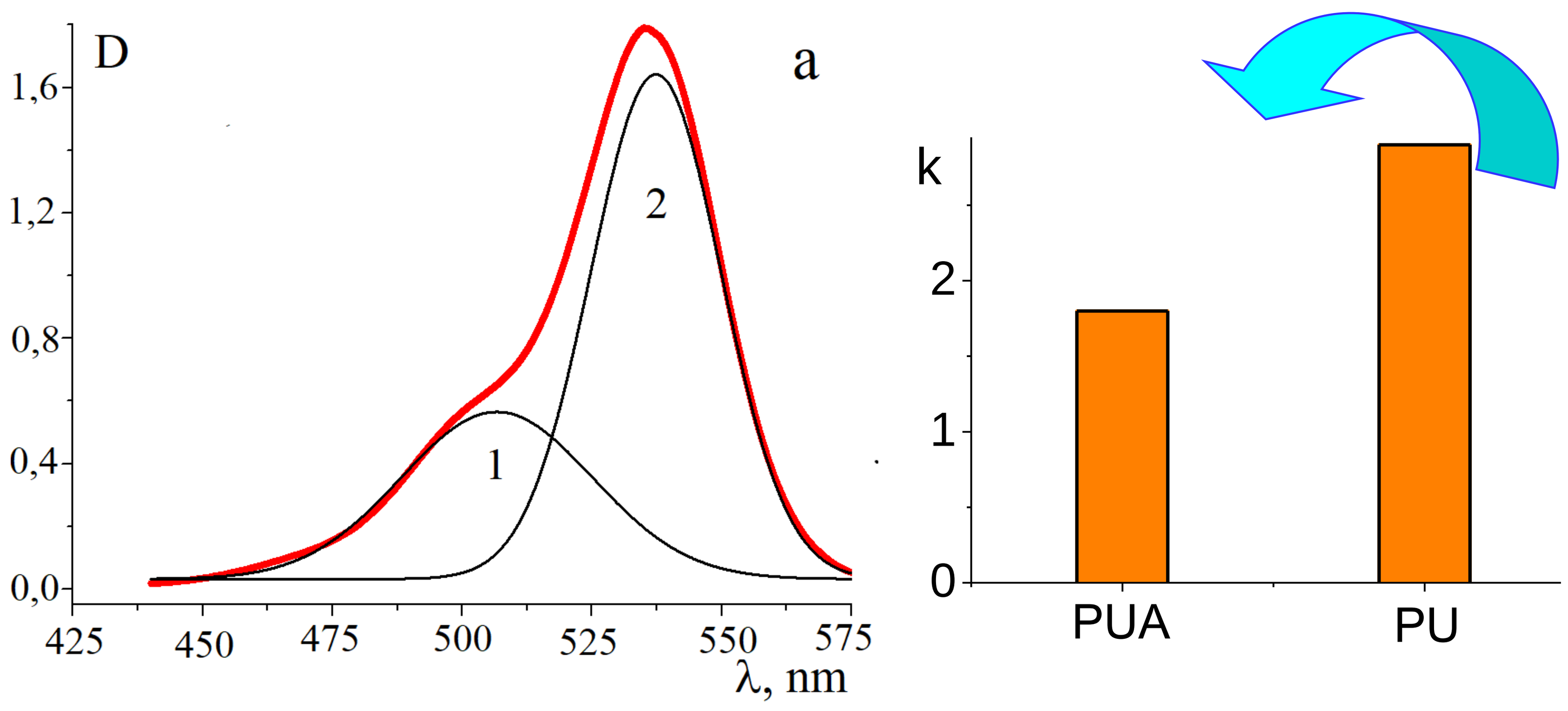


Fig 1. The absorption spectra of the R6G, their graphical decompositions in the PU, the PUA and monomer/dimer ratio, k

The analysis of the graphical decomposition made by the Origin software for the absorption spectra of the R6G xanthene dye in the PU and PUA matrices has revealed the larger monomer/dimer ratio (k) for the dye molecules in the polymer of higher polarity.

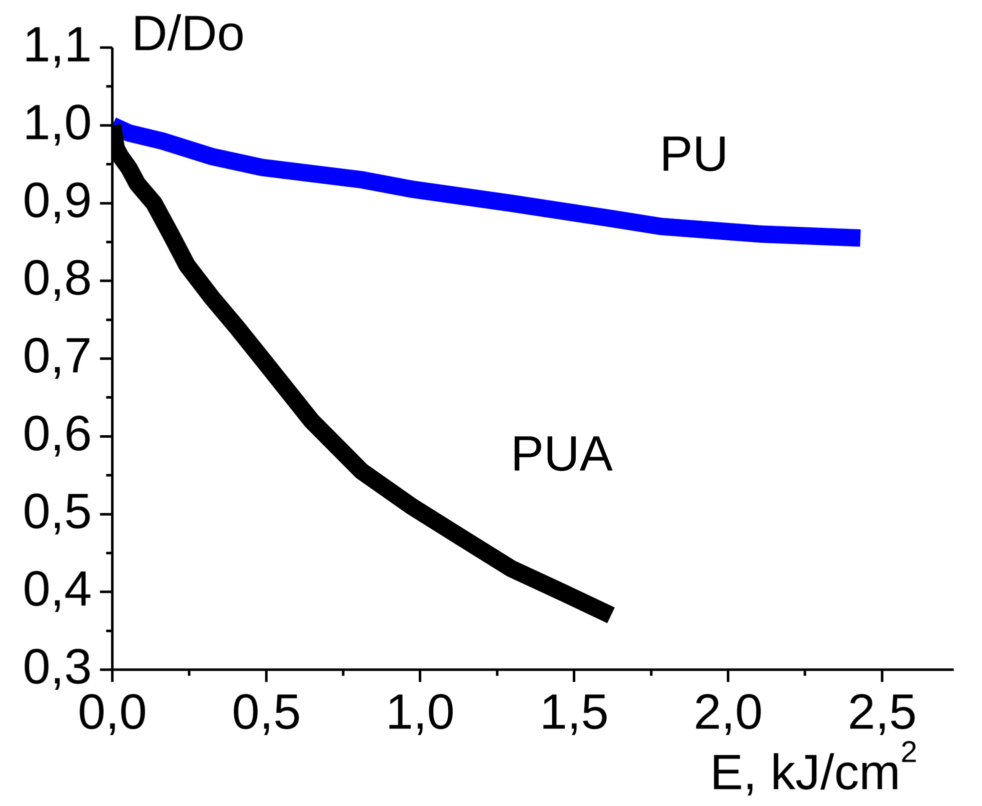


Fig 2. Changes in the optical density of the R6G in the PU and the PUA, depending on the irradiation energy

The significant role is also played by intermolecular interactions between the dye and PU on the properties of the polymer matrix itself.

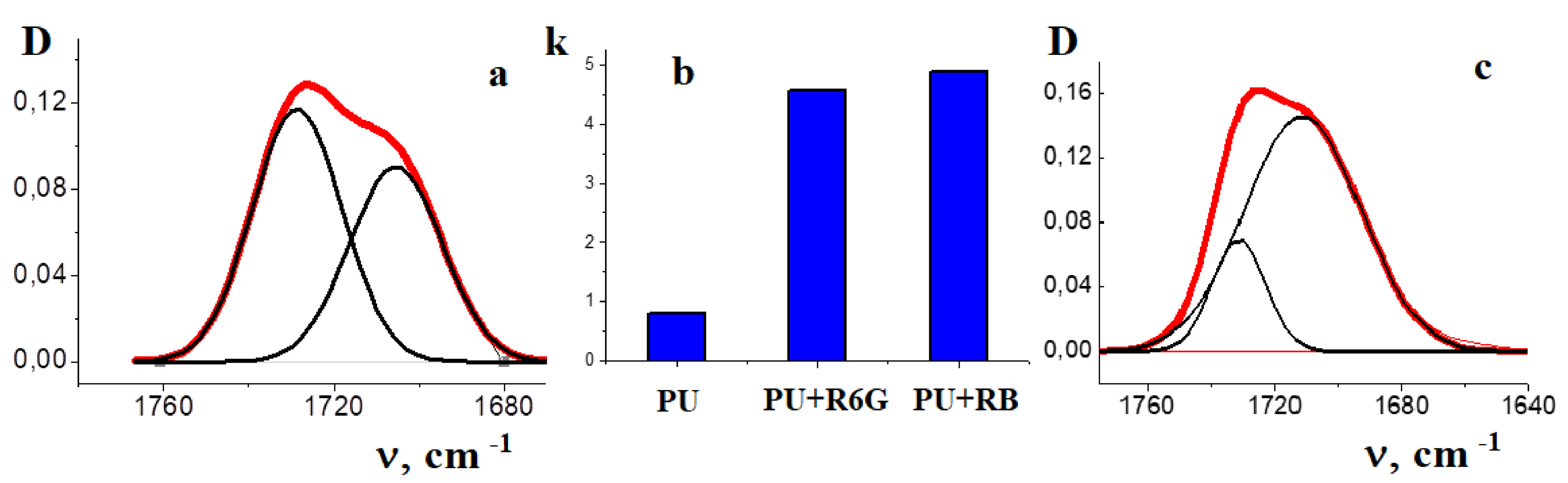


Fig 3. Graphical decomposition of a IR-spectrum fragment with the C=O group stretching vibrations: a - PU; c - PU+R6G, and changes in the intensity redistribution of the high- and low-frequency components (b)

Analysis of the IR-spectra of the PU doped with the xanthene dyes R6G and RB, shows that in the presence of dyes, self-association of urethane groups in the middle of the macrochain rigid segment prevails, and their interaction with flexible polyether fragments is weakened (fig. 3).

The obtained data has shown that the lower elastic modulus E' (dynamic mechanical analysis data) and higher gas permeability of the polymer (electron paramagnetic resonance using a paramagnetic probe) can cause a decrease in the induced pressure, and therefore, an improvement of the polymer radiation resistance (tabl).

Table DMA and EPR data for the original and dye-doped PU

Samples	DMA data E'$_{T=25\,^{o}C}$, MPa	EPR data P/Po, relative units
PU	17.18	1.00
PU+R6G	7.43	1.34
PU+RB	7.04	1.04

P/Po is the relative integrated intensity of the pmp spectrum in the PU

The results obtained are important in determining the possibility of using the PU doped with xanthene dyes as laser solid-state active elements.