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THE EFFECT OF γ–IRRADIATION ON THERMAL STABILITY UREA-FORMALDEHYDE RESIN WITH TIO_2 AND FURFURYL ALCOHOLE

V. Jovanović[1], S. Samaržija-Jovanović[1], G. Marković[2], M. Marinović-Cincović[3]

[1]*Faculty of Natural Science and Mathematics, University of Priština:(vojani@sbb.rs)*
[2]*Tigar, Nikole Pašića 213, 18300 Pirot, Serbia,*
[3]*University of Belgrade, Institute of Nuclear Science Vinča,*

Abstract
The thermal stability of organic-inorganic nano-composites prepared by a two-stage polymerization of urea-formaldehyde resin (UF) with furfuryl alcohol (FA) and TiO_2 before and after irradiation has been investigated. The two resins of urea-formaldehyde–TiO_2 composites, namely: ***Resin 1*** (UF+TiO_2) and ***Resin 2*** (UF + TiO_2 + FA), were synthesized. The thermal stability of obtained materials was studied by non-isothermal thermo-gravimetric analysis (TG), differential thermal gravimetry (DTG) and differential thermal analysis (DTA). UF hybrid composites have been irradiated (50 kGy) and after that their radiation stability was evaluated on the basis of thermal behavior. The free formaldehyde percentage in all prepared samples was determined. DTG peaks of both UF resin are shifted to a higher temperature after irradiation. The minimum percentage values of free formaldehyde (4% and 3%) for ***Resin 1*** and ***Resin 2***, respectively, after irradiation dose of 50 kGy are detected.

Introduction
UF resins offer unique potential technical advantages in a variety of applications, in abundance unmatched in the competing product. Among those advantages are the above-mentioned low price, the nontoxicity of resin and resin products, and the environmental compatibility of resin bonded products, such as particleboard. As a typical amino resin, UF resin adhesive possesses some advantages, such as fast curing, good performance in the panel, water solubility and lower price [1]. Formaldehyde emissions from pressed-wood products used in home construction was one of the affecting sick building syndromes in an indoor environment. The release of formaldehyde is predominantly determined by the mole ratio of formaldehyde to urea in the adhesive system. The lower mol ratio and the lower post-production formaldehyde emission are out of the produced board. High-energy radiation is a well-known technique for modification of polymers. However, little work concerning the effects of γ-irradiation on the thermal properties of modified UF resins has been done. The goal of this work was to determine the radiation stability of the synthesized TiO_2-based urea–formaldehyde

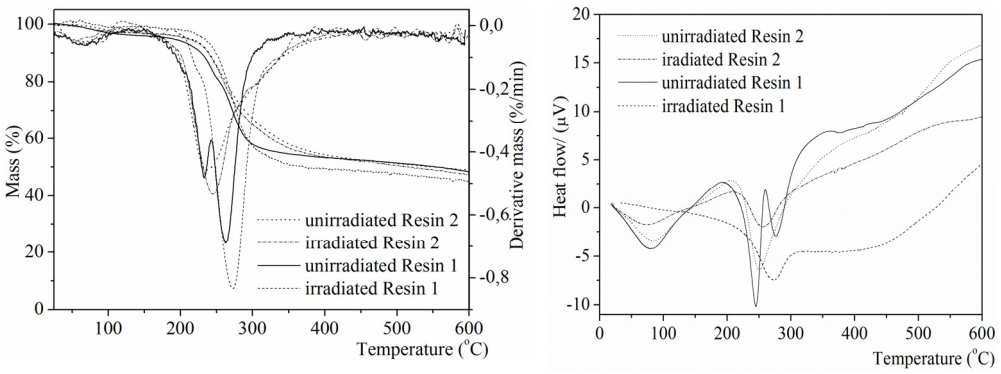
(UF) composite materials based on their thermal behavior. The thermal behavior of two types of TiO_2-based UF resin (unirradiated and irradiated) was investigated using non-isothermal TGA, DTG and DTA.

Experimental

The following materials were used in the study reported here: Urea (Alkaloid-Skopje, FYR of Macedonia); 35% formaldehyde (Unis-Goražde, Bosnia and Herzegovina); furfuryl alcohol and TiO_2 (Sigma-Aldrich, Germany). Two types of TiO_2-based UF hybrid composites with formaldehyde-to-urea (F/U) ratio of 0.8 were synthesized using the same procedure. Irradiations were performed in air in the Co-60 radiation sterilization unit with the dose rate of 10 $kGyh^{-1}$ and the total absorbed dose of 50 kGy.

Results and Discussion

The thermal behavior of unirradiated and irradiated UF resins samples occurs in three and two main stages (Figure 1). The mass loss at different temperatures is summarized in Table 1. The rate of the thermal decomposition reaction before and after irradiation, shows more than one maximum rate with temperature is increasing. This behavior indicated that thermal decomposition of these resin passed through multiple stages, depending on the state of decomposition and not on the components [2,3].



a) b)

Figure 1 TGA/DTG (a) and DTA (b) curves of unirradiated and irradiated UF resin.

High-energy radiation is a well-known tool for the modification of polymers. In polymer irradiation, two phenomena occur at the same time: cross-linking and chain scission. The balance of cross-linking and scission reactions in polyolefin chains, exposed to high-energy radiation processes that produce free radicals, may result in good properties and new applications.

Table 1. DTG, DTA data of peak values, and total mass loss for unirradiated and irradiated UF resins.

Samples	Dose of γ-irradiation (kGy)	DTG peak values (°C)	DTA Endothermic peak values (°C)	Total mass loss (%)	Free formaldehyde (%)
Resin 1 UF + TiO_2	0	75.1 233.1* 263.8*	80.8 245.8 276.6	51.9	15
	50	70.8* 93.8* 161.1 273.3	274.4	54.5	4
Resin 2 UF + TiO_2 + FA	0	63.9 236.2	85.2 250.6	51.0	10
	50	59.2 245.6	76.1 256.3	52.7	3

*overlapping peaks

Conclusion

1. The free formaldehyde percentage for TiO_2-based UF resin modified with FA is less than for unmodified UF resin. The free formaldehyde percentage is significantly reduced after γ-irradiation.
2. DTG peaks of both UF resins are shifted to a higher temperature after γ-irradiation.
3. The total mass loss for TiO_2-based UF resin modified with FA is less than that of unmodified UF resin.

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