**Results of Examples and Synthesis Process for Increasing the Temperature Resistance of Wood Materials**

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**Abstract.** The reaction mechanisms of the samples were developed. Thus, the reaction kinetics were analyzed, the reaction temperatures were optimally selected in each batch, and the kinetics of the sample were calculated on this basis. We can see that the temperature resistance of the obtained sample increased due to the sulfur-nitrogen bond and after adding calcium to the sample. We know that organic compounds containing calcium chloride and barium chloride salts, that is, inorganic substances, are temperature resistant. The obtained mixture, together with the wood, provides temperature resistance of polymeric materials. This substance, along with its thermostability, also exhibits adhesive properties when used as an adhesive for wood materials and polyethylene products. The obtained sample was tested on pine wood, which is currently used in the attic of houses. To test the temperature resistance of the sample, tests were carried out on an electric furnace. The oxygen content in the room is 21%. The wood samples were prepared according to GOST standards. Initially, the wood samples were immersed in a solution dissolved in water for twenty minutes.

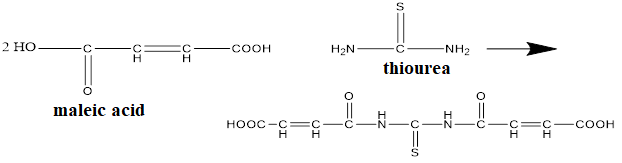
**Keywords:** maleic acid, thermally stable substance, chromato-mass spectrum, radical, ion, carboxyl group, oligomer, polymer, BIA (The conditional name of the synthesized compound)

**INTRODUCTION**

The presence of calcium and barium carboxylate groups in polymers providing thermal stability, while groups such as imine and hydroxyl ensure photostability, has been widely reported in the literature. Based on this, the synthesis of the BIA oligomer and the production of a thermally stable coating on its basis are carried out in two stages. In the first stage, 23.2 g of maleic acid and 6 g of thiourea were added together and stirred; at a reaction temperature of 140 °C the substances transitioned to a liquid state, forming a colorless liquid mass based on maleic acid and urea, and at 170 °C the mixture boiled and polymerized, yielding a yellow-colored mass. The reaction mechanism involves the carbon atoms bonded by the double bond in maleic acid, where one hydrogen atom attached to the nitrogen atom in urea breaks the double bond and forms a bond with the nitrogen atom. As a result, a yellow adduct mass was formed. In the second stage, the obtained adduct was reacted with 16.5 mL of crotonaldehyde; the mixture was stirred at 190 °C, and the crotonaldehyde was added dropwise. The reaction was continued until a viscous mass was formed. The oxygen atom involved in the double bond of crotonaldehyde breaks the hydrogen bond associated with the nitrogen in the adduct, forming an –OH group, and the carbon atom bonds with the nitrogen. The reaction kinetics of the obtained thermally stable product were developed.

**METHODS**

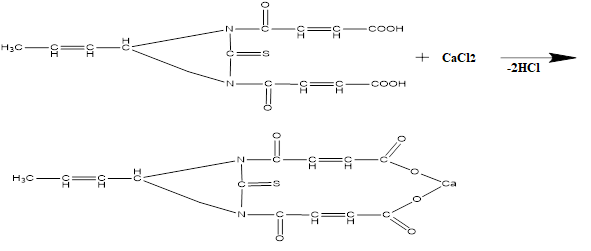
The use of dicarboxylic acids such as maleic acid in the synthesis of heat-resistant polymers is well documented. Their unsaturated and bifunctional structure enables a wide variety of reactions, including esterification, amidation, and radical polymerization, leading to the formation of complex networks.



**The reaction equation for maleic acid and urea in the first stage**



It is considered appropriate to modify the obtained sample in order to improve its properties. Crotonaldehyde was used as the modifier. The purity of crotonaldehyde was first checked, and only then was it introduced into the reaction. Crotonaldehyde was purified using an extractor.



To increase the thermal resistance of the obtained intermediate product, calcium chloride or barium chloride should be used. To enhance the temperature resistance of the resin, an inorganic substance was incorporated into the molecular structure of the compound (Table 1).

**TABLE 1.** Investigation of the photostability of BIA obtained from local raw materials

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Experiment №** | **Ratio of compound** | **Temperature (°C)** | **Pressure (atm)** | **Time (hour)** | **Yield (%)** |
| 1 | 2:1 | 130-140 | 1-1,2 | 1 | 78 |
| 2 | 1:1 | 150-160 | 1-1,2 | 2 | 85 |
| 3 | 1:1 | 170-180 | 1-1,2 | 2 | 90 |

The photostability of the synthesized compound was studied using conventional methods. In this study, the photostability after its incorporation into polyethylene was investigated. Currently, global plastic production amounts to 140 million tons per year. The relative proportions of individual thermoplastic polymers are approximately: 25% polyethylene, 20% polyvinyl chloride, 15% polystyrene, with the remaining half corresponding to other polymers (Table 2).

**TABLE 2.** Composition of the coating-forming mixture

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **№** | **Amount of synthesized BIA %** | **Amount of liquid glass, %** | **Amount of acrylic emulsion, %** | **Amount of kaolin, %** | **Adhesion value**  **N/m²** |
| 1. | 2 | 4 | 90 | 4 | 56 |
| 2. | 4 | 8 | 80 | 8 | 51 |
| 3. | 6 | 12 | 70 | 12 | 48 |
| 4. | 8 | 16 | 60 | 16 | 44 |
| 5. | 10 | 20 | 50 | 20 | 41 |
| 6. | 12 | 24 | 40 | 24 | 37 |
| 7. | 14 | 28 | 30 | 28 | 32 |

When studying the change in thermal stability of wood treated with the prepared coatings, it was observed that as the amount of kaolin increased, the coating exhibited movement under the effect of temperature, limiting the possibility of investigating it as a thermally stable coating (Table 3).

**TABLE 3.** Change in thermal stability of wood treated with the prepared coatings

|  |  |  |
| --- | --- | --- |
| **№** | **Maximum temperature point,** °C | **Change** |
| 1. | 320 | Carbonization |
| 2. | 338 | Carbonization |
| 3. | 345 | Carbonization |
| 4. | 378 | Carbonization |
| 5. | 381 | Carbonization |
| 6. | 280 | The coating flowed or sagged |
| 7. | 290 | The coating flowed or sagged |
| Blank | 180-185 | Ignition |

It is known that under the influence of light, humidity, high temperature, and other factors, various physicochemical processes occur in oligomers, leading to the deterioration of their valuable properties. During service, these factors, together with mechanical stress, cause even more complex processes in the oligomers. To improve the photostability of polyethylene, a small amount of BIA polymer is added as a stabilizer. They not only expand the processing temperature and application range of polyethylene, but also increase its service life by 3–10 times. Increasing the service life of polyolefins by adding stabilizing additives is relatively economical, since introducing additional BIA containing –OH and –NH groups as stabilizers incurs far lower costs than establishing the production of a new oligomer. The presence of –OH and –NH groups in the BIA oligomer provides resistance to UV radiation under vacuum conditions; during this process, photodegradation occurs, macromolecules crosslink, and as hydrogen is released, double bonds are formed simultaneously with the generation of methane and ethylene.

**TABLE 4.** Dependence of the change in polyethylene’s characteristic viscosity on irradiation time

|  |  |  |
| --- | --- | --- |
| **№** | **Irradiation time, hours** | **Intrinsic viscosity, dL/g** |
| 1 | 5,0 | 3,4 |
| 2 | 25,0 | 0,9 |
| 3 | 50,0 | 0,5 |
| 4 | 75,0 | 0,4 |
| 5 | 100,0 | 0,3 |

Stabilized samples of polyethylene obtained under low pressure were prepared as follows: polyethylene and 0.001–0.1 wt.% BIA were dissolved in dimethylformamide, and the resulting suspension was coagulated using alcohol. When polyethylene film samples are irradiated with UV light using a mercury-quartz lamp in the presence of air, carbonyl (C=O) groups, hydroxyl (OH) groups, and bonds accumulate in the material. At 50 °C, the induction period for the accumulation of oxygen-containing groups is 50–60 hours, while at 90 °C it is 10 hours. The dependence of their accumulation on the irradiation time (τ > τ\_ind) follows a linear relationship (Table 4). During photo-oxidative degradation, low-pressure polyethylene changes more rapidly compared to high-pressure polyethylene.

**TABLE 5.** Dependence of the change in relative elongation at break (ε) and tensile strength at break (σᵣ) on UV irradiation time

|  |  |  |  |
| --- | --- | --- | --- |
| **№** | **UV irradiation time, hour** | **Relative elongation at break, ɛ 10-2,%** | **Tensile strength at break, σr MPa** |
| **QMPE** | **QMPE** |
| 1 | 5,0 | 7,5 | 24,0 |
| 2 | 25,0 | 3,0 | 22,0 |
| 3 | 50,0 | 1,2 | 17,0 |
| 4 | 75,0 | 0,2 | 9,0 |
| 5 | 100,0 | - | 10,0 |

The reduced thermal degradation of polyethylene treated with the photostable polymer compared to untreated polyethylene indicates its photostability (Table 5).

Polyethylene mixed with high-pressure BIA oligomer containing –OH and –NH groups crosslinks significantly under UV irradiation compared to low-pressure polyethylene and all molecular olefins, due to the increased branching of its macromolecules. When polyethylene film samples are irradiated at room temperature using a PRK-4 lamp, the photochemical reaction, specifically structural crosslinking, is nearly twice as slow in high-pressure polyethylene mixed with BIA oligomer containing –OH and –NH groups compared to low-pressure polyethylene.

As shown in the table, the decrease in polyethylene mass up to 700 °C indicates increased photostability compared to untreated polyethylene. The process was analyzed up to the onset of char formation (Figure 1).

**FIGURE 1.** Dependence of polymer mass loss of 0.02% on temperature.

A regression equation was developed to describe the dependence of mass loss (%) of the sample, measured at the required percentage, on temperature. It was observed that mass loss increases with rising temperature. When the temperature was raised from 50 °C to 700 °C, mass loss of the polyethylene sample was recorded. To assess the accuracy of the mass loss percentage when the temperature was increased in 50 °C increments, a regression equation was derived. The regression equation has a coefficient of determination R2 = 0.9954, indicating a level of accuracy close to 1 (Figure 2).

**FIGURE 2.** Dependence of polymer mass loss of 0.04% on temperature.

The diagrams below show that when 0.04% of polymer oligomer containing –OH and –NH groups is added to polyethylene, its photostability increases. If the oligomer content is increased further, it leads to embrittlement of the polyethylene; therefore, the optimal amount was taken as 0.04% (Figure 3).

**FIGURE 3.** Dependence of polymer mass loss of 0.06% on temperature

As the percentage of BIA in the sample increased, the bonds in polyethylene were strengthened, resulting in enhanced photostability. A regression equation was developed to confirm the accuracy of the obtained results. It was observed that photostability decreases with increasing temperature, and the corresponding mass loss is expressed in percentages (Figure 4).

**FIGURE 4.** Dependence of polymer mass loss of 0.08% on temperature

Thus, in low-pressure polyethylene samples, the number of double bonds relative to the total amount of functional groups is the highest. Based on the conducted studies, the addition of 0.08% was found to exhibit the best properties. Additionally, polyethylene contains certain amounts of carboxyl, carbonyl, lactone, and ester groups.

**CONCLUSION**

In this study, the thermal resistance and reaction kinetics of the thermally stable substance were investigated. Additionally, the photostability of the sample was analyzed, and the obtained sample was mixed with polyethylene in specific ratios to examine its resistance to light. Aqueous solutions of the thermally stable substance were prepared in concentrations ranging from 2% to 10% and applied to wood samples by spraying and impregnation. The treated wood samples were subjected to temperature, and their initial and final masses were measured to determine the amount of mass lost in grams. In conclusion, this work demonstrates a viable approach for producing environmentally friendly, heat-resistant, and flame-retardant materials from bio-derived precursors. The integration of structural–property analysis, spectroscopic characterization, and flammability testing provides a comprehensive foundation for the further development of advanced materials in applications where fire resistance is critical. Future studies can investigate the effects of different BIA concentrations, synergistic additives, and processing methods on performance, scalability, and long-term stability.

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