POLYMETHYLSILSESQUIOXANE OLIGOMERS AS ECOLOGICALLY FRIENDLY BINDING AGENTS FOR PARTICLE BOARDS

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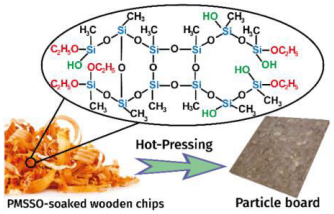
E. A. Litvinov,[a] D. M. Borisova,[a,b] A. A. Kalinina,*[a,b] E. S. Afanasyev,[b] O. A. Serenko,[b] and A. M. Muzafarov[a,b]

[a] *Enikolopov Institute of Synthetic Polymeric Materials, Russian Academy of Sciences, ul. Profsoyuznaya 70, Moscow, 117393 Russia*
[b] *Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, ul. Vavilova 28, str. 1, Moscow, 119334 Russia*

Abstract

The possibility of using multifunctional methylsilsesquioxane oligomers as ecologically friendly binding agents for wood chipboards is investigated. The physical and mechanical properties of the resulting particle boards are studied and compared with those of the boards containing a formaldehyde resin as a binder.



Key words: hydroxy-containing methylsilsesquioxane oligomers, green chemistry, particle boards.

Introduction

Particle boards (PBs) are composite materials consisting of wood industry waste (sawdust, wood shavings, chips), polymer binders, and functional additives. They are widely used in building industry and furniture production owing to the low cost, high strength characteristics, and processability [1]. The main binding agents used in the production of PBs are formaldehyde-based resins: phenol formaldehyde resins (PFRs), melamine formaldehyde resins (MFRs), and urea formaldehyde resins (UFRs). UFRs are generally applied all over the world. Their advantages include the low cost, ease of use (under various curing conditions), relatively low curing temperatures, resistance to microorganisms, low abrasion resistance, excellent thermal properties, and a clear or light color (especially when the resin is hardened). The main disadvantage of UFRs is the lack of resistance to high humidity, especially with increasing temperature [2].

PFRs have good water resistance, which makes them suitable for the production of external wooden products. However, an important drawback of formaldehyde binders for wood is the release of formaldehyde, which is a human carcinogen [3]. This fact led to intensive research in the field of modifying classic formaldehyde resins to improve the ecological safety of production and subsequent use of PBs [4–6], as well as their replacement with environmentally benign formaldehyde-free binders, including those made from renewable biomaterials: the derivatives of lignin, starch, and tannins, as well as their combinations with polyvinyl alcohol, silica, liquid glass, *etc.* [7–9].

Another effective ecologically friendly alternative to formaldehyde resins may be the use of organosilicon binding agents, which are bioinert and innocuous for the environment [10]. In this respect, of particular interest are polyhydroxy-substituted methylsilsesquioxane oligomers (MSSOs) [11–13]. These are low-molecular, highly reactive oligomers, soluble in a water–alcohol medium, which easily enter into polycondensation reactions and are capable of chemically interacting with hydroxy groups of wood, which potentially determines their applicability as binding agents for PBs. The goal of this work was to study the possibility of application of water–alcohol solutions of MSSOs as independent ecologically friendly binding agents for PBs, free of formaldehyde.

Results and discussion

Figure 1 shows a photograph of the resulting board samples based on MSSO. Boards 1 and 2, characterized by the density of 350 and 470 kg/m^3, respectively, are brittle and delaminate when sawing. Boards 3–5, with the density of 540, 760, and 630 kg/m^3, respectively, withstand sawing. The test samples were made from them. Sample 4 demonstrated the best physical and mechanical properties.

Figure 1. Resulting board samples.

The reference samples were commercial particle boards: non-moisture-resistant and moisture-resistant boards of grades P2 and P5, respectively. According to the results of the performed investigations, the best sample 4 based on the new binding agent appeared to be inferior to the commercial PB samples in mechanical characteristics: the ultimate bending strength was 5.7 MPa *vs.* 16.9 and 19.1 MPa in the case of P2 and P5, respectively, the ultimate compressive strength was 5.29 *vs.* 12.3 and 10.9 MPa, respectively. However, the resulting samples significantly surpassed the commercial PBs in the water

absorption and swelling properties. The reference samples were characterized by an increase in the mass and thickness after testing, even in the case of moisture-resistant P5 board. The water absorption and swelling of board 4 based on MSSO binder was 10.4 wt % and 4.3%, while those for board P5 were 16.8 wt % and 5.7%.

Therefore, a basis for the production of ecologically friendly PBs was created, which features great development potential. Further optimization of the composite composition, the methods of applying the binder and pressing conditions will afford eco-particle board samples with physical and mechanical properties comparable to those of the traditional PBs.

Experimental section

A 44 wt % water–alcohol solution of MSSO, a product of the hydrolytic polycondensation of triethoxymethylsilane (see Scheme S1 in the Electronic supplementary information (ESI)), was used as a binding agent. The synthesis was carried out in an autoclave at 85 °C for 3 h at the $MeSi(OEt)_3/H_2O$ molar ratio of 1:1.5.

The analysis of the composition and molecular weight characteristics of MSSO using ^1H NMR spectroscopy and gel permeation chromatography (Figs. S1, S2 in the ESI) showed that the oligomer contained 5 and 18 wt % of hydroxy and ethoxy groups, respectively, and was characterized by a monomodal molecular weight distribution, M_{peak} = 600 Da, M_w = 870 Da, M_n = 670 Da, and MWD = 1.3.

Wood chips, the basis of PBs, from spruce and pine species, consisted of three fractions: large (chip lengths from 200 to 530 mm), medium (chip lengths from 50 to 199 mm), and small (less than 50 mm). The ratio of the large/medium/small fractions was 1:3:8. The average width and thickness of the chips (for the main small fraction) were 7 mm and 0.02 mm, respectively. The moisture content of the chips was 6–9%.

The composition for pressing was prepared by mixing the chips with a 44 wt % water–alcohol solution of MSSO, varying the binder content from 20 to 50 wt % based on the filler mass, kept at room temperature in the open mode for 1 h, and then packed in a sealed container for transportation and pressing. During the tests, it was found that the optimal composition was one with the MSSO content of 30 wt % based on the filler mass. Further optimization of the pressing conditions was carried out using this composition.

The boards with the sizes of 250×250×16 mm were produced from the resulting compositions by hot pressing on a KuPY 400 autom press. The pressing mode was selected by analogy with the pressing mode of the PBs with formaldehyde binding agents: temperature 90–120 °C, pressure 7–10 MPa, time 90–120 min.

The physical and mechanical properties were studied on a RKM 5.2 svo series testing machine. The mechanical properties, humidity, water absorption, and swelling of the composites were measured according to the *GOSTs* (State Standards) *10632-2014* and *32399-2013*.

Conclusions

Therefore, a basis for the production of ecologically friendly PBs was created, which features great development potential. Further optimization of the composite composition, the methods of applying the binder and pressing conditions will afford ecoparticle board samples with physical and mechanical properties comparable to those of the traditional PBs.

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Corresponding author

* E-mail: kalinina@ispm.ru (A. A. Kalinina).

Electronic supplementary information

Electronic supplementary information (ESI) available online: the synthetic details; the GPC and NMR data. For ESI, see DOI: 10.32931/io2419a.

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