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IMPROVEMENT OF WATER-BASED WOOD COATING PERFORMANCE – MTMOS REACTIVITY WITH WOOD

The study analyzed the reactivity of wood with water-based systems containing methyltrimethoxysilane (MTMOS) and an acrylic binder. A structural analysis of wood treated with organosilanes and then extracted with water, was performed using (Fourier transform infrared spectroscopy (FTIR). In the FTIR spectra, the analyzed bands included 1250 cm^{-1}which are responsible for vibrations of SiC and/or SiO groups. These bands are characteristic for silicon bonds with atoms of carbon and oxygen originating from the methoxy groups found in organosilanes. The presence of these bands in the spectra proves the occurrence of a reaction between wood and MTMOS. The concentration of silicon was determined by Atomic absorption spectroscopy (AAS) in treated wood and then extracted with water.

Keywords: wood coatings, organosilanes, acrylic resin, MTMOS, FTIR, AAS

Introduction

Wood coatings based on acrylic resin modified with silicon compounds considerably diminish the water uptake of this material. A structural analysis of the bonds between the basic chemical compounds and silicone compounds of wood can determine the developed structures and explain the chemical reactions. This explains the effectiveness of silicone compounds as agents increasing the resistance of wood to water, and thus to biotic degradation. Donath et al. [2007] treated wood with alkoxysilanes and other organofunctional silanes. The method relies on the

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hydrolysis of alkoxysilanes and the subsequent condensation of the silanol groups formed within the porous wood surface. This was shown to be an effective method of reducing the water uptake of wood after cyclic water immersion and drying exposure [Tingaut et al. 2006]. The enhanced dimensional stability observed after these treatments is due to the replacement of hydrophilic hydroxyl groups with hydrophobic substances.

The aim of this study was to investigate the reactivity of the wood with an aqueous coating system based on acrylic resin, containing MTMOS.

Material and methods

The reaction of a water-based system containing organosilane (methyltrimethoxysilane (MTMOS, $CH_3Si(OCH_3)_3$) and acrylic resin (Findisp A10) was run through deionized water solutions at room temperature at different volumetric ratios. The homogenous wood material - Scots pine sapwood (*Pinussylvestris* L.), in the form of powder, was treated with silane systems (1/25 w/v) at room temperature with simultaneous stirring with a magnetic bar stirrer for 2 hours. The wood samples were left in working solutions at room temperature for another 2 hours, then filtered and dried in air flow at room temperature. The obtained materials were leached using continuous extraction with deionized water, at a constant ratio (1/100 w/v) for 2 hours. Homogeneous samples of the wood material, of 5 g each, were collected from the test material just after treatment, as well as after being subjected to leaching.

Infrared Spectroscopy

The wood powder samples were mixed with Potassium bromide KBr at a 1/200 mg ratio. The spectra were registered using an Infinity Series Fourier-transform spectrophotometer (ATI Mattson) at a range of 500–4000 cm^{-1} and at a resolution of 2cm^{-1},registering 64 scans.

Atomic Absorption Spectrometry

The samples were mineralized in a Marsxpress CEM International semi-closed microwave mineralization system. The solutions obtained by the digestion were analysed for silicon contents by flame atomic absorption spectrometry (FAAS) using the Spectra 200 AA spectrometer Varian. The final results were median values of three simultaneous measurements. Analytical curves were prepared on the basis of a series of freshly prepared standard solutions with a silicon concentration of 1000 mg/dm^3.

Results and discussion

Fig. 1a and 1c present the FTIR spectra of wood following a reaction with MTMOS and acrylic resin (i.e. after wood treatment), while fig. 1b and 1d – those of wood after reaction and elution (i.e. after water leaching of treated wood).

It should be emphasized here that a new band of 1750 cm^{-1} was found in all spectra after the reaction of homogenous wood with the tested system. The new band is responsible for the stretching vibrations of the C=O group. The presence of this band indicates the conversion of wood treated with acrylic resin. This band is visible also on IR spectra after extraction, which indicates a permanent bond between the acrylic resin and the wood components.

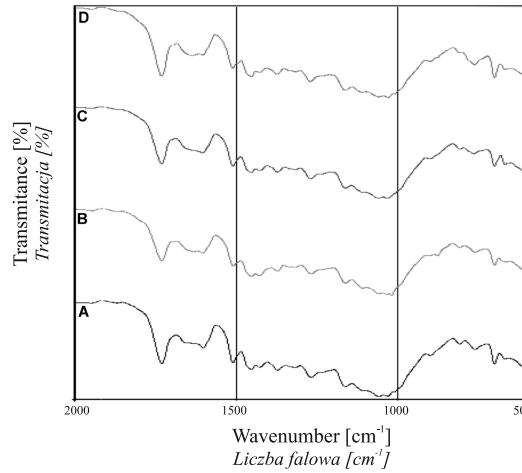

Fig. 1. Spectra of wood after reaction with MTMOS 1%/acrylic resin 20% (A), wood after extraction with water (MTMOS 1%/acrylic resin 20%) (B), wood after reaction with MTMOS 2.5%/acrylic resin 20% (C), wood after extraction with water (MTMOS 2.5%/acrylic resin 20%) (D)
Rys. 1. Widma drewna po reakcji z MTMOS 1%/żywica akrylowa 20% (A), drewna po ekstrakcji wodą (MTMOS 1%/żywica akrylowa 20%) (B), drewna po reakcji z MTMOS 2,5%/żywica akrylowa 20% (C), drewna po ekstrakcji wodą (MTMOS 2,5%/żywica akrylowa 20%) (D)

Following the reaction with the systems of acrylic resin/MTMOS, a band of 1250 cm^{-1} characteristic for Si-C and/or Si-O bonds was recorded in the wood spectra. This band is also found in the wood spectra after extraction. This is characteristic for a silicon bond with carbon and oxygen atoms originating from the methoxy group present in organosilanes [Ghosh et al. 2009; Sèbe et al. 2004; Tjeerdsma, Millitz 2005]. The results of the AAS analysis (silicone concentration) confirm a high reactivity of wood components with the tested system. The highest values of the silicon concentration in the wood, amounting to 320 mg/kg, were recorded for the wood samples treated with 20% acrylic resin and 5% MTMOS.

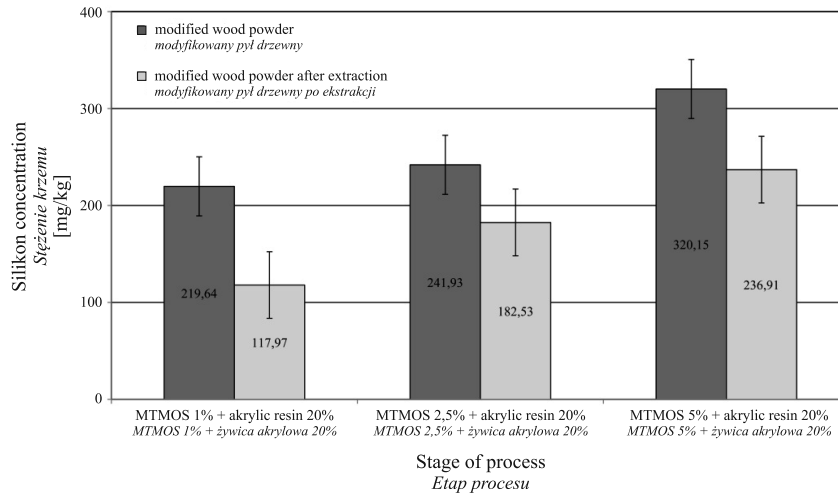

Fig. 2. Silicon concentrations in wood after reaction with MTMOS/acrylic resin and in wood after extraction with water
Rys. 2. Stężenie krzemu w drewnie po reakcji z MTMOS/żywica akrylowa oraz w drewnie po ekstrakcji wodą

A very low percentage of silicon elution from wood, at its simultaneous high reactivity, is particularly evident in the case of the system of 20% acrylic resin/ 5% MTMOS. This shows a permanent chemical bond between organosilane and wood, which was not broken in the process of hydrolysis.

Conclusions

The presence of bands at 1250 cm^{-1}(from thebSiC and SiO groups) characteristic for vibrations of silicon-carbon and silicon-oxygen bonds, shows a chemical reaction between wood and MTMOS. There are bands responsible for vibrations of $SiOCH_3$ on IR spectra of wood treated with a system and then subjected to leaching. The presence of these bands proves the permanent character of bonds between the hydroxyl and methoxy groups of organosilanes. These Si-O-C bonds are susceptible to hydrolysis. The high concentration of silicon in treated wood after extraction was compared to the silicon concentration in wood after reaction with MTMOS. The results confirm the permanent character of the bond between wood and treatment system.

Acknowledgement

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References

Donath S., Militz H., Mai C. [2007]: Weathering of silane treated wood. Holz a. Roh. u. Werkst. [65]: 35–42

Ghosh S.C., Militz H., Mai C. [2009]: The efficacy of commercial silicones against blue stain and mould fungi in wood. Eur. J. Wood Prod. [67]: 159–167

Sèbe G., Tingaut P., Safou-Tchiama R., Petraud M., Grelier S., De Jeso B. [2004]: Chemical reaction of maritime pine sapwood (PinuspinasterSoland) with alkoxysilane molecules: A study of chemical pathways. Holzforschung[58]: 511–518

Tingaut P., Wiegenand O., Militz H., Sèbe G. [2006]: Chemical reaction of alkoxysilane molecules in wood modified with silanol groups. Holzforschung[60]: 271–277

Tjeerdsma B.F., Millitz H. [2005]: Chemical changes in hydrothermal treated wood: FTIR analysis of combined hydrothermal and dry heat-treated wood, Holz a. Roh. u. Werkst. [63]: 102–111

POPRAWA PARAMETRÓW WODOROZCIEŃCZALNEJ POWŁOKI DO DREWNA – REAKTYWNOŚĆ MTMOS Z DREWNEM

Streszczenie

Celem pracy było zbadanie reaktywności drewna sosny zwyczajnej (*Pinus sylvestris* L.) z wodnym systemem powłokowym na bazie żywicy akrylowej, zawierającym MTMOS (metylotrimtoksysilan). Analizę strukturalną drewna po reakcji z MTMOSi żywicą akrylową oraz po ekstrakcji wodą, wykonano metodą spektroskopii w podczerwieni (FTIR). Przedstawione wyniki analizy strukturalnej drewna z MTMOS wskazują na wysoką reaktywność badanego organosilanu z substancją drzewną. Zarejestrowane pasma absorpcji na widmach IR drewna po reakcji z MTMOS, jak i po ekstrakcji wodą (1250 cm^{-1}) są odpowiedzialne za drgania grupy SiC i/lub SiO. Pasma te zarejestrowane na widmach IR drewna z MTMOS są charakterystyczne dla wiązania krzemu z atomem węgla i tlenu pochodzącym od grupy metoksylowejobecnej w organosilanie. Obecność tych pasm na widmie świadczy o zajściu reakcji między pyłem drzewnym a organosilanem. Potwierdzeniem jest wysokie stężenie krzemu wykazane w analizie AAS. Bardzo niski procent wymycia krzemu z pyłu drzewnego, przy wysokiej jego reaktywności, jest szczególnie widoczny w przypadku mieszaniny: 20% żywicy akrylowej z udziałem MTMOS o stężeniu 5%, jak również MTMOS o stężeniu 2,5%.

Słowa kluczowe: powłoki do drewna, organosilany, żywica akrylowa, MTMOS, FTIR, AAS