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Preliminary investigations of preparations of liquefied-wood/nanoparticles wood coatings

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By

Dr. Anuj Kumar

Department of Building Structures, Faculty of Civil Engineering, Czech Technical University in Prague

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DATA SHEET

COST MC Chair: Prof. Dr. Stefanie Wieland

Host: Prof. Dr. Marko Petrič

Place: University of Ljubljana

Department of Wood Science & Technology

Ljubljana, Slovenia

Beneficiary: Dr. Anuj Kumar, Ph.D.

Czech Technical University in Prague

Department of Building Structures, Faculty of Civil Engineering

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Contents

Summary

New bio-based wood coatings were investigated and developed. As a binder, a sustainable natural resource liquefied wood (LW) was used to synthesize the polyurethane for wood coatings, instead of resins made of crude oil derivatives. The main goal was to develop a novel bio wood coating, which would be comparable to commercial wood coatings with synthetic resins (i.e. synthetic polyurethane), so by aesthetical, as well as by mechanical properties. In order to reach the goal, LW was used, and nanocellulose was added as a nanofiller. The curing and rheological properties of LW and nanocellulose were investigated using a rheometer. The second objective was to enhance the water stability of LW based coating by deposition of silica nanoparticles via the sol-gel method.

Introduction

Due to environmental reasons, there is an increased interest in alternative sustainable sources for fuels, chemicals, and materials. Biomass is also seen as a promising alternative. Its conversion into a liquid solution that can be used as an intermediate in the preparation of plastics, adhesives, and coatings has attracted much attention in recent years. Several liquefaction processes have been developed such as pyrolysis, liquefaction in hot-compressed water, or solvolyses with cyclic carbonates, phenols, or polyhydric alcohols.[1,2,3] There are several, but rare reports on use of liquefied ligno-cellulosic material for film and/or coating preparation.[4,5,6]

The drawbacks of liquefied lignocellulosic based wood coatings are their dark brown or even black colour and some inherent properties,[1] hindering their further development into commercial products and low stability in humid conditions. It is also known, that nanoparticles in coatings may positively influence on their characteristics.[8]

The main objective of this STSM was to perform preliminary studies on development of wood coating formulations on the basis of LW and in combination with nanoparticles, of a quality, comparable to that of some commercial wood coatings.

Research Methodology

Liquefaction of Wood*:* The liquefaction experiments of wood dust (poplar, spruce) were performed with glycerol, in the presence of H_2SO_4 as a catalyst. The hydroxyl numbers and acidic values were determined using the methods given in literature.[9]

Preparation of Two-component PU Coatings from Liquefied Wood

To formulate air-drying two-component PU coatings, we used an aromatic polyisocyanate based on toluene diisocyanate (Desmodur L 75 from Bayer Material Science LLC). The ratio

between hydroxyl number of the LS and NCO content in the Desmodur L75 was 1:1.2 (to ensure that all OH groups in the LS would react with the NCO groups from Desmodur L75).

Incorporation of Nanoparticles into LW Based Coatings: The most important innovation of this step is enhancement of LW based coating properties by application of nanoparticles. The nanocellulose was added (3wt% of LW) to liquefied wood based coatings for investigating the curing and rheological properties. In addition, in another set of experiments, the nanosilica particles were deposited via sol-gel technique on the LW coated samples and we investigated the morphological properties using scanning electron microscopy (SEM).

Rheological & Curing Properties of Commercial PU, LW And LW/Nanocellulose: The viscoelastic and curing behavior of a commercial PU, LW-PU and LW-PU-NFC samples was determined using an ARES G2 rheometer (TA instruments) equipped with 25 mm parallel-plate configuration. All measurements were carried out using two steps procedure. The samples were first heated from 25 °C to 80 °C, 90 °C, 100 °C and 110 °C, respectively, with a heating rate of 10K/min and then maintained at final temperature for 90 minutes. The effects of thermally induced gelation on the viscoelastic characteristic functions (storage modulus, loss modulus, complex viscosity and tanδ) were evaluated for all type of samples..

Results

Morphology of LW Coating Along With Nanosilica Deposition

To understand the cured morphology of LW and LW/nanosilica on wood surfaces, the SEM analyses were carried out. Fig. 1a shows the SEM image of neat spruce wood, the wood cell wall is without any coating. Fig. 1b shows the LW coated wood sample; the morphology of LW coat does not appear uniform and did not cover the wood cell walls completely, this

might be due to penetration of LW into to wood surface and creation of the gaps, and air bubbles in the LW coat on wood surface.

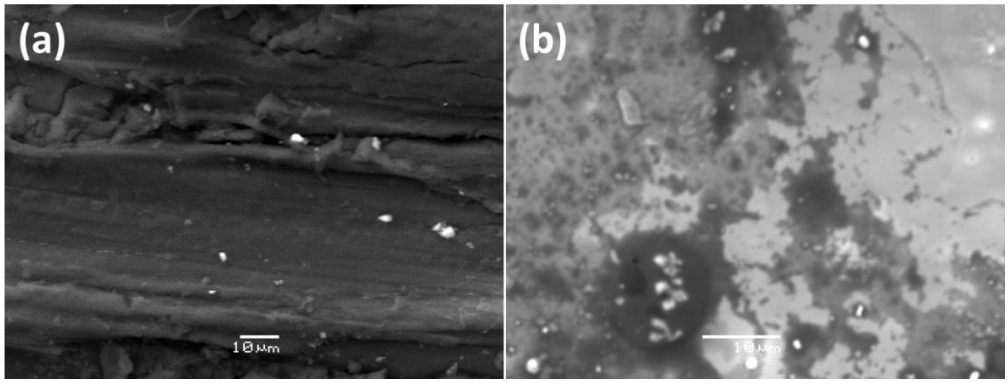

Figure 1: SEM images of (a) spruce wood and (b) LW coated spruce wood.

Figure 2 shows the morphology of nanosilica deposited LW coating on wood surface. Three different concentrations of nanosilica in the solvent were used to deposit nanosilica. Fig 2a shows the nanosilica at 1% concentration sample: the nanosilica particles are formed on the surface of LW coating. At 2% concentration the nanosilica particle deposition increases when compared to 1% concentration sample, as shown in Fig. 2b. At 3% concentration the nanosilica particle size and percentage of particle deposition again increases, the particles are turned into the nano size flakes.

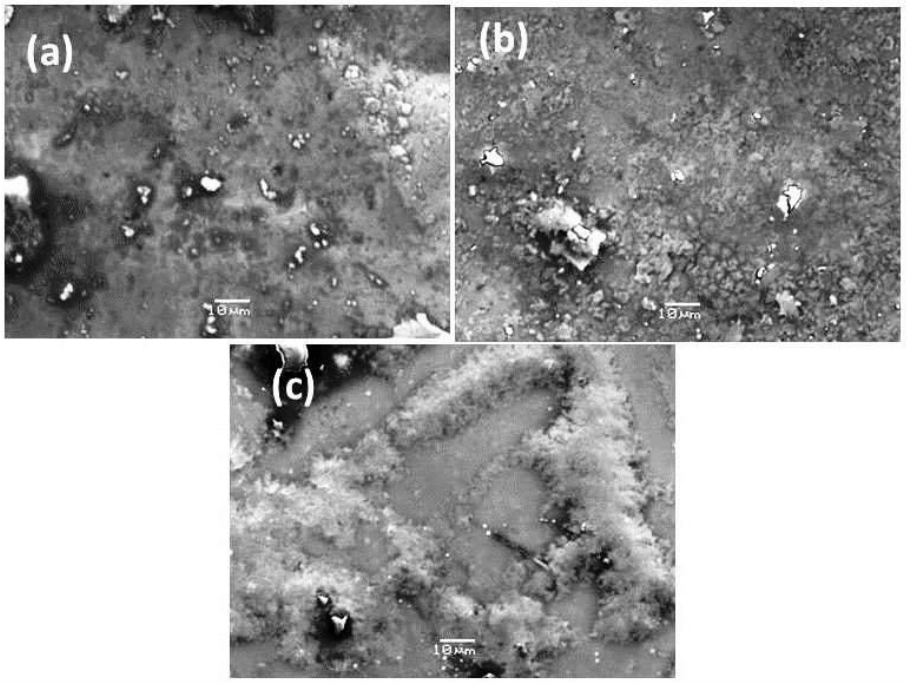

Figure 2: Nanosilica deposited on LW coated wood samples with three different concentrations of nanosilica in the solvent.

Viscoelastic and Rheological Properties of Commercial PU, LW-PU and LW-PU/Nanocellulose

The viscoelastic properties of all three samples were evaluated using parallel plates rheometer in forms of storage modulus, loss modulus, and complex viscosity. This analysis was not completed during the STSM tenure, some of the remaining analyses are in progress. Some of the results are presented in the Figures 3-7. My host of this STSM will complete this study by carrying out the analysis and when all the results are available, the overall comparison will be completed. The effects of nanocellulose of the properties of LW-PU will be concluded after the analysis of results.

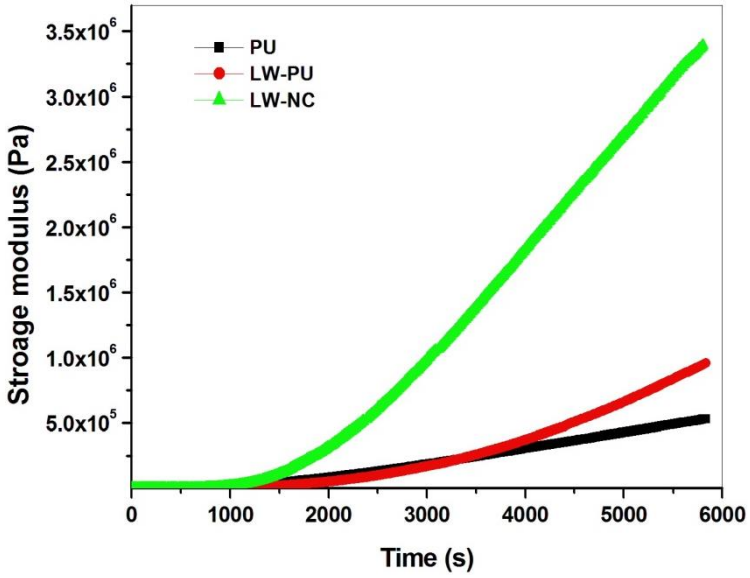

Figure 3: Storage modulus of all three types of polyurethane samples at 80 °C for 90 minutes of curing.

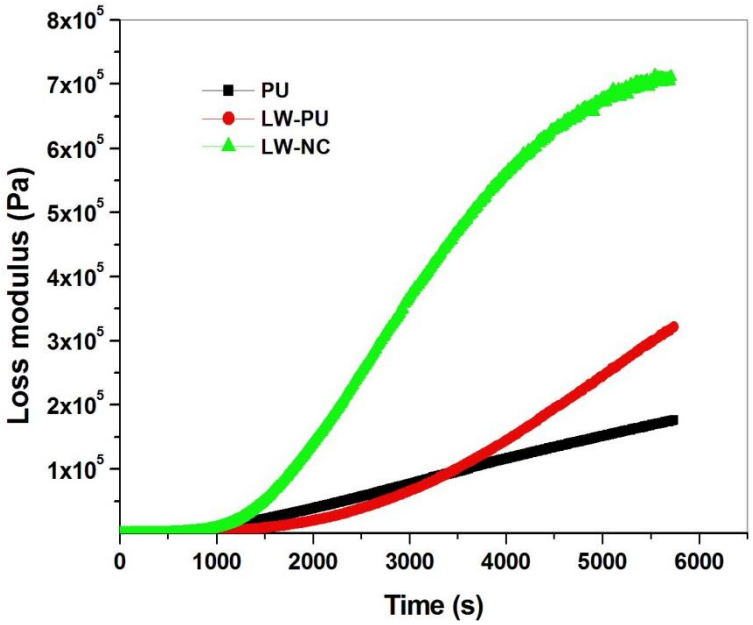

Figure 4: Loss modulus of all three types of polyurethane samples at 80 °C for 90 minutes of curing.

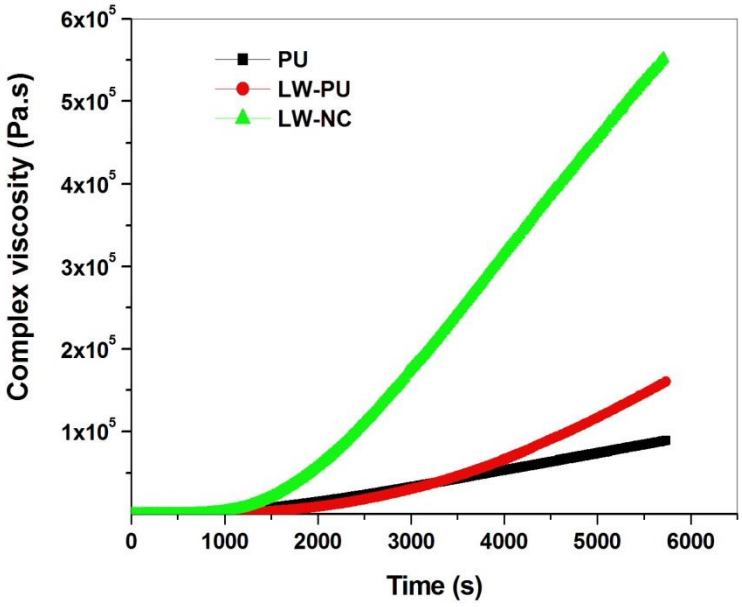

Figure 5: Complex viscosity of all three types of polyurethane samples at 80 °C for 90 minutes of curing.

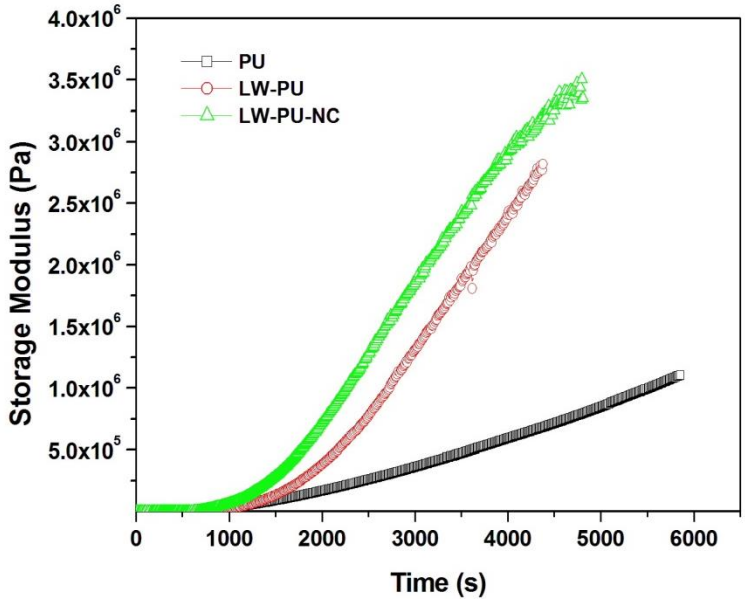

Figure 6: Storage modulus of all three types of polyurethane samples at 100 °C for 90 minutes of curing.

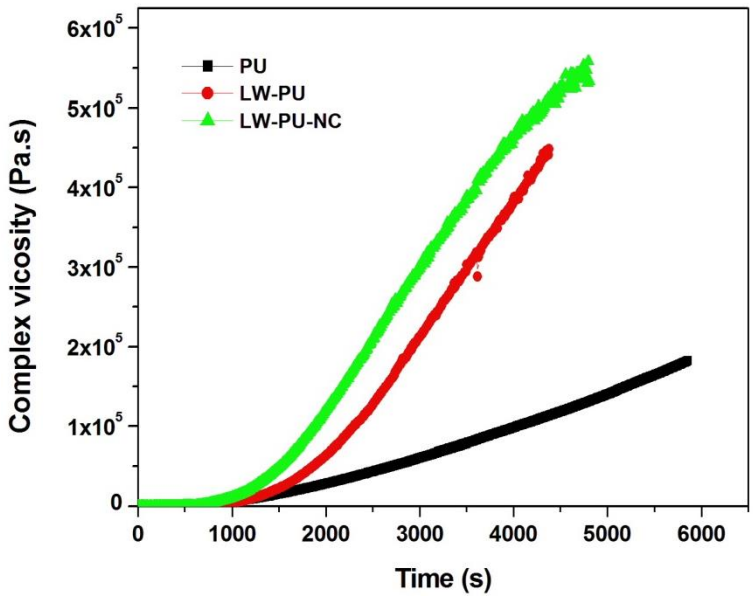

Figure 3: Complex viscosity of all three types of polyurethane samples at 100 °C for 90 minutes of curing.

Conclusions

A new kind of analysis was carried out to investigate the effects of two different nanofillers on the curing and coating properties of bio-based LW-polyurethane wood coatings. Nanosilica was successfully deposited on the LW coating over wood surface, and this coating had an enhanced resistance to water by creating the nanosize rough surface over LW coating. This research of nanosilica deposition on LW based coatings is being continued by the host.

The second aim of this STSM was to investigate the effects of nanocellulose on the curing and rheological properties. I used only single weight percentage of nanocellulose due to limitation of time. The coating properties with other shares of nanocellulose are also currently investigated by my STSM host. Further, they will investigate the coating properties of LW/nanocellulose polymers.

Gain of Knowledge

This was my first COST STSM and I am happy to say that my experiences were very positive. This kind of funding system enables and encourages young researchers to visit colleague organisations to learn to use new devices and collect data not measurable at the home institute. Naturally, the cooperation and encounters with colleagues both widened my scientific network as well as built up the professional skills.

These measurements helped me to understand and study the LW synthesis, analysis, and preparations of LW based coatings for wood. During this STSM for the first time I learned the rheological analysis of polymers.

Acknowledgements

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