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Author(s)	SUGIYAMA, Masaki; OBATAYA, Eiichi; NORIMOTO, Misato
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## Viscoelastic Relaxation of Chemically Treated Woods\*<sup>1</sup>

Masaki SUGIYAMA\*<sup>2</sup>, Eiichi OBATAYA\*<sup>2</sup>  
and Misato NORIMOTO\*<sup>2</sup>

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This paper deals with the viscoelastic relaxation for four kinds of chemically treated wood.

Figure 1 illustrates the dynamic modulus and the loss tangent along the grain at 11 Hz as functions of temperature for dry untreated and treated spruce (*Picea sitchensis*) specimens. Three types of relaxation, being labelled  $\alpha_U$  to  $\gamma_U$  in order of decreasing temperature, were detected in the untreated wood. These  $\alpha_U$  to  $\gamma_U$  relaxations are respectively attributed to the micro-Brownian motion of the main chains in the non-crystalline region, the motion of the adsorbed water molecules and the motion of the CH<sub>2</sub>OH groups.

Three relaxations of  $\alpha_F$  to  $\gamma_F$  were observed for the formaldehyde-treated wood (WPG: 4.6%). This treatment involves the crosslinking of chains by OCH<sub>2</sub> bridges. The micro-Brownian motion of the main chains may be restricted to some extent by this crosslinkage, resulting in a lowering of the  $\alpha_F$  loss. The  $\beta_F$  peak was slightly lower compared to the  $\beta_U$  peak, which can be ascribed to the reduction in hygroscopicity of the treated wood. The  $\gamma_F$  peak was slightly higher than the  $\gamma_U$  peak. This treatment reduces the OH group and increases the OCH<sub>2</sub> group. The OCH<sub>2</sub> peak was observed in almost the same temperature range in the cellulose derivatives with this group. Therefore, this relaxation may involve both the motions of the remained CH<sub>2</sub>OH groups and the introduced OCH<sub>2</sub> groups.

The acetylated wood (WPG: 20.3%) had two relaxations of  $\alpha_A$  to  $\beta_A$ . In this treatment hydrophilic OH groups are substituted with hydrophobic and bulky COCH<sub>3</sub> groups. The introduction of the bulky COCH<sub>3</sub> group may reduce the cohesive forces between the main chains. Thus, the modulus decreased and the loss increased remarkably above 100°C. The  $\beta_A$  peak temperature was observed between the  $\beta_U$  and  $\gamma_U$  peak temperatures. The  $\beta_A$  location was close to the peak temperature due to the COCH<sub>3</sub>

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\*<sup>2</sup> Laboratory of Property Enhancement.

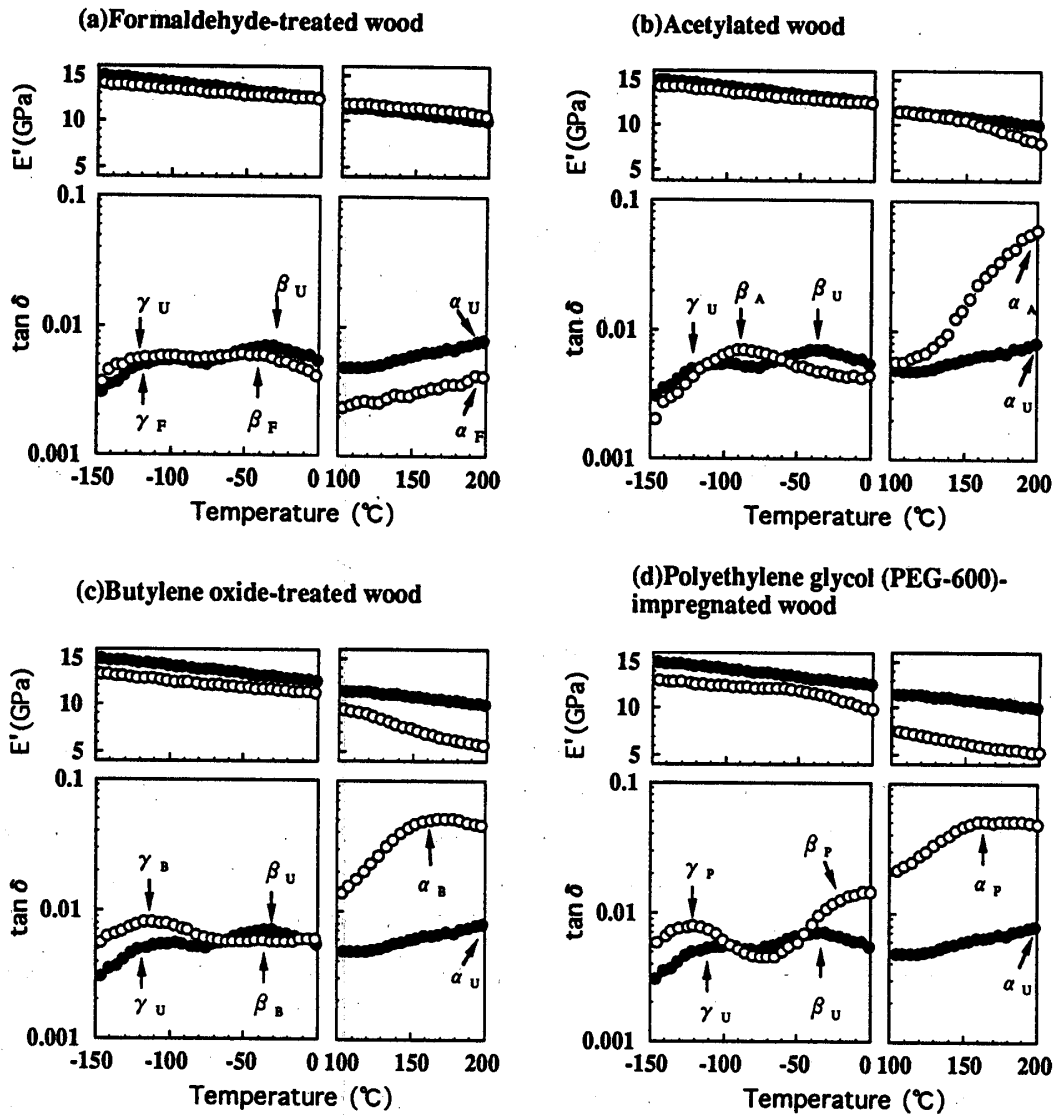


Fig. 1. Dynamic modulus  $E'$  and loss tangent  $\tan \delta$  along the grain at 11 Hz plotted against temperature for dry untreated (●) and chemistry treated (○) woods.

groups in acetylcellulose. This relaxation is probably due to the motion of the  $\text{COCH}_3$  groups.

For the butylene oxide-treated wood (WPG : 25.1%) three relaxations of  $\alpha_B$  to  $\gamma_B$  were detected. This treatment results in bonded cell-wall bulking as in the case of acetylation except that the introduced groups are hydrophilic. The  $\alpha_B$  relaxation due to the micro-Brownian motion of the main chains exhibited a marked peak within the temperature range examined. A considerable lowering of the peak temperature and the loss increase by this treatment could be ascribed to the introduction of flexible bulky groups in the main chains. The treatment reduces the hygroscopicity of wood at low relative humidity levels, so that the  $\beta_B$  relaxation due to the absorbed water became less distinct. The treatment reduces the

CH<sub>2</sub>OH groups and increases the OCH<sub>2</sub> groups. The  $\gamma_B$  peak occurred at the same temperature as the corresponding peak for the cellulose derivatives with the OCH<sub>2</sub> group. Therefore, the motions of the OCH<sub>2</sub> groups may be responsible for this relaxation.

Three relaxations of  $\alpha_P$  to  $\gamma_P$  were detected in the polyethylene glycol (PEG-600)-impregnated wood (WPG: 49.7%). A considerable lowering of the  $\alpha_P$  peak temperature could be ascribed to the plasticization of the cell wall by the PEG molecules. The  $\beta_P$  relaxation appeared by the introduction of the PEG molecules and may be due to their macro-Brownian motion. The  $\gamma_P$  peak was rather large and its location shifted apparently to a lower temperature to the  $\gamma_U$  peak. Therefore, this relaxation can involve the segmental motion of the PEG molecules as well as the motion of the CH<sub>2</sub>OH groups.