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Application of Near Infrared Spectroscopy (NIR) to light-irradiated wood

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Materials and methods

Specimens prepared under air-dried condition were the sapwood of Japanese cypress (*Chamaecyparis obutusa*), and the heartwood of Japanese cedar (*Cryptomeria japonica*), Japanese beech (*Fagus crenata*), and hackberry (*Celtis occidentalis*). The dimension of each sample was 50 mm in width, 50 mm in length, and 10 mm in thickness. This widelong surfaces (i.e. flat grain) were irradiated with simulated sunlight from a carbon arc for up to 80 hours. After the samples recovered their air-dried condition, the following measurements were performed. The color of specimens was measured by a colorimeter (SE-2000: Nippon Denshoku Industries Co., Ltd.). The CIELAB color parameters (L*, a*, and b*) were obtained from the colorimeter and the difference in the L* (i.e.; ΔL*) and chroma coordinates (i.e.; Δa* and Δb*) were calculated. The measured colors before light-irradiation for each sample were used as control. Table 1 shows the color of specimens before irradiation. Near infrared (NIR) diffusely reflected spectra ranging from 800 to 2500 nm with an increment of 10 nm were measured using a spectrophotometer (InfraAlyzer 500: Bran + Luebbe Co.).

Results

For all wood species, Δb* increased as the light-irradiation time t_{ir} increased, whereas ΔL* decreased with the increment of t_{ir}. Such phenomena mean that the sample have yellowed by the light-irradiation. Δa* also increased gradually as t_{ir} increased except Japanese cedar. Figure 1 shows the variation of the second derivatives of absorbance $d^2Ab/d\lambda^2$ at 1112 and 1784 nm with the irradiation time, respectively. These absorption bands are assigned to the second overtone of CH stretching vibration in aromatic skeletal and the first overtone of CH stretching vibration, respectively. $d^2Ab/d\lambda^2$ at 1112 nm decreased rapidly with increment of t_{ir}, and approached the constant value. However, $d^2Ab/d\lambda^2$ at 1784 nm versus t_{ir} showed an opposite behavior. In either absorption band, the changes in $d^2Ab/d\lambda^2$ up to t_{ir}=10 hr were remarkable.

Figure 2 shows the spectral variation of the correlation coefficient r between $d^2Ab/d\lambda^2$ and Δb*. In this figure, the typical second derivative spectrum of Japanese cypress is also depicted. The wavelength dependency of r showed almost similar tendency independent of wood species. In the near infrared range, the absorption band assigned to CH in aromatic skeletal showed a high negative correlation. r around 1700 nm may be affected by CH stretching vibration in CH_3 resulting in the irregular variation of them. On the other hand, the absorption band assigned to OH in water and CH in CH_3, CH_2, and CH showed high positive correlations.

These results clearly indicate that the light absorption of CH in the aromatic skeletal increased with the increment of irradiation time. It is also observed that the light absorption of OH in water and CH in CH_3, CH_2, and CH decreases as t_{ir} increases. The trend of CH in aromatic skeletal with the irradiation time is not inconsistent with previous reports (Tolvaj and Faix 1995,

Table 1. The color of specimens before irradiation
Tabelle 1. Farbwerte der Proben vor der Bestrahlung

Species	L*	a*	b*
Japanese cypress	82.50 ± 0.51	3.80 ± 0.59	22.81 ± 0.70
Japanese cedar	69.72 ± 1.17	11.57 ± 0.53	21.81 ± 0.39
Japanese beech	71.50 ± 1.31	6.45 ± 0.93	19.45 ± 0.80
Hackberry	82.45 ± 1.73	2.13 ± 0.56	21.36 ± 1.83

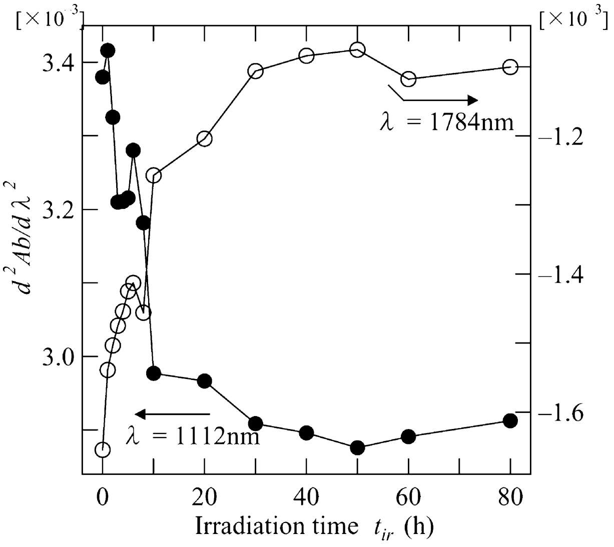

Fig. 1. Variation of second derivatives of absorbance with irradiation time of Japanese cypress. $d^2Ab/d\lambda^2$ = second derivative of absorbance; t_{ir} = irradiation time (h); λ = wavelength (nm)
Bild 1. Verlauf der 2. Ableitung der Extinktion mit der Bestrahlun gsdauer von Zypressenholz; $d^2Ab/d\lambda^2$ =2. Ableitung der Extinktion; t_i = Bestrahlungsdauer; λ = Wellenlänge (nm)

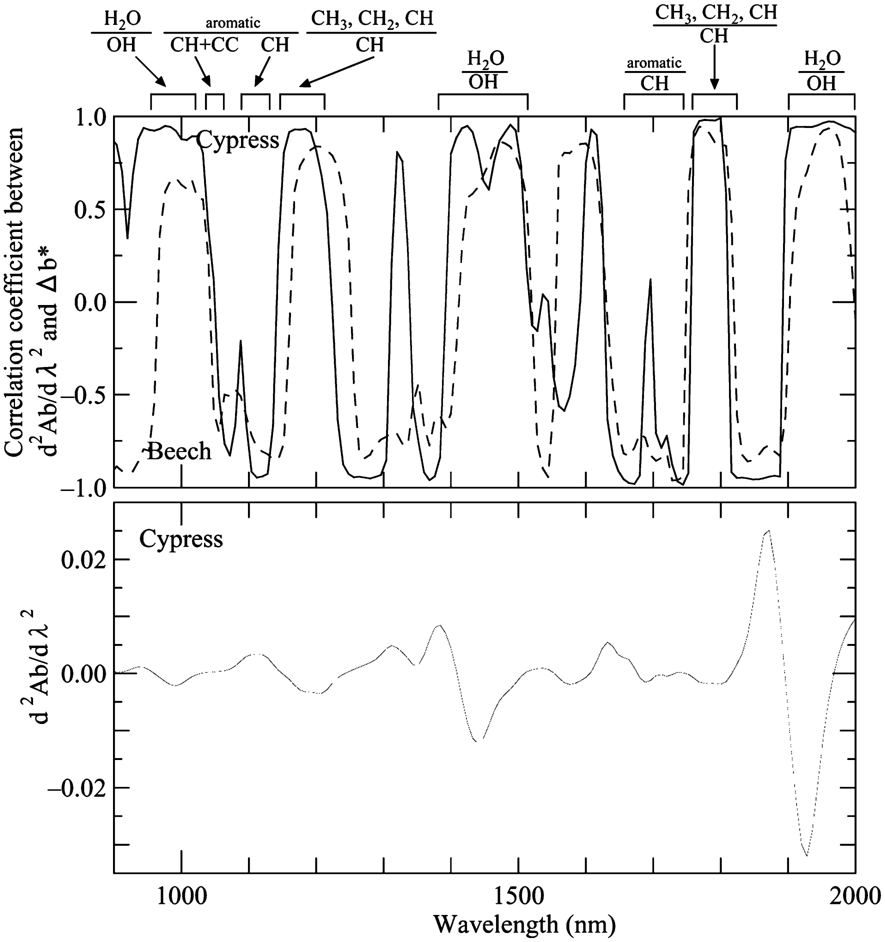

Fig. 2. Correlation coefficient of the relation between the second derivative of absorbance and the color parameter Δb*, and second derivative spectra
Bild 2. Korrelationskoeffizient der Beziehung zwischen der 2. Ableitung der Extinktion und dem Farbparameter Δb* sowie Spektren der 2. Ableitung

Barta et al. 1999). It is furthermore assumed that the equilibrium moisture content of wood decreased due to light irradiation. Thereby, we may conclude reasonably that the adsorbility of water in wood varied with the light-irradiation time, however, it is questionable, whether this affects the change in color of wood or not. This point will be examined in following reports. Near infrared spectroscopy proves to be a useful method allowing the detection of changes in chemical structure of wood after light-irradiation. It may also be suitable for the realization of a new coloring method of wood (Mitsui et al. 2001).

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