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Chemical differences between sapwood and heartwood of *Chamaecyparis obtusa* detected by ToF-SIMS

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ABSTRACT

Time-of-flight secondary ion mass spectrometry (ToF-SIMS) was used to investigate the distribution of elements, Na, Mg, Al, K, and Ca, and lignin, in the contiguous growth rings including the sapwood/heartwood boundary in Hinoki cypress (*Chamaecyparis obtusa*). Lignin was distributed almost uniformly from sapwood to heartwood. The concentrations of most of the elements showed a drastic increase or decrease in the transition zone between sapwood and heartwood. The ToF-SIMS mapping analysis showed that most of the elements predominantly localized in the ray parenchyma cells in the inner transition zone and heartwood, while the elements showed no localization and distributed almost uniformly in the outer transition zone near sapwood. The result suggests that the ray parenchyma cells play a role in behaviors of elements during the transition from sapwood to heartwood.

1. Introduction

Sapwood and heartwood are recognizable in cross section of stems in most wood species (Fig. 1), the former is a pale-coloured outer zone, and the latter is a dark-coloured inner core [1]. Sapwood is converted into heartwood eventually, which is accompanied by various changes including death of living cells and the accumulation of extractives. The heartwood extractives are reported to be synthesized in a transition zone between sapwood and heartwood [1]. Generally, the transition zone is a relatively narrow zone and can be recognized by a paler colour than sapwood and heartwood, as shown in Fig. 1.

Investigation of chemical differences between sapwood and heartwood is important to understand the formation mechanism of heartwood. The main structural components of woods are polysaccharides, cellulose and hemicellulose, and an aromatic polymer, lignin. Heartwood generally contained less cellulose and more lignin [2]. The distribution of mineral elements from sapwood to heartwood is important to understand wood chemistry and environmental science, such as pollution events. The concentrations of elements in woods are well investigated using diverse techniques including instrumental neutron activation analysis (INAA) [3,4], inductively coupled plasma-mass spectroscopy (ICP-MS) [5], and secondary ion mass spectrometry (SIMS) [6]. The difference in the concentration between sapwood and heartwood varies from elements to elements, and species to species [7].

In this report, we used Hinoki cypress (*Chamaecyparis obtusa*) wood sample preserved at −80 °C by freezing in liquid nitrogen immediately after felling to investigate the distribution of elements, Na, Mg, Al, K, and Ca, from sapwood to heartwood by time-of-flight secondary ion mass spectrometry (ToF-SIMS). Freezing treatment immediately after cutting the tree may retain the distribution of chemical components including elements as they exist in vivo. We focused the behavior of

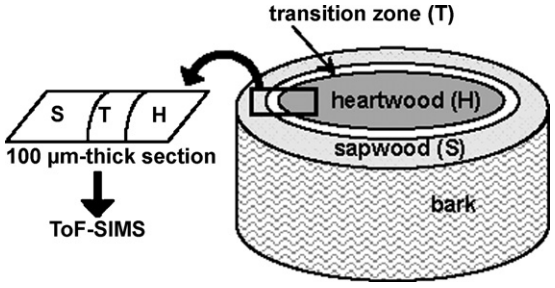

Fig. 1. An illustration of transverse section of wood stem showing heartwood, transition zone, and sapwood.

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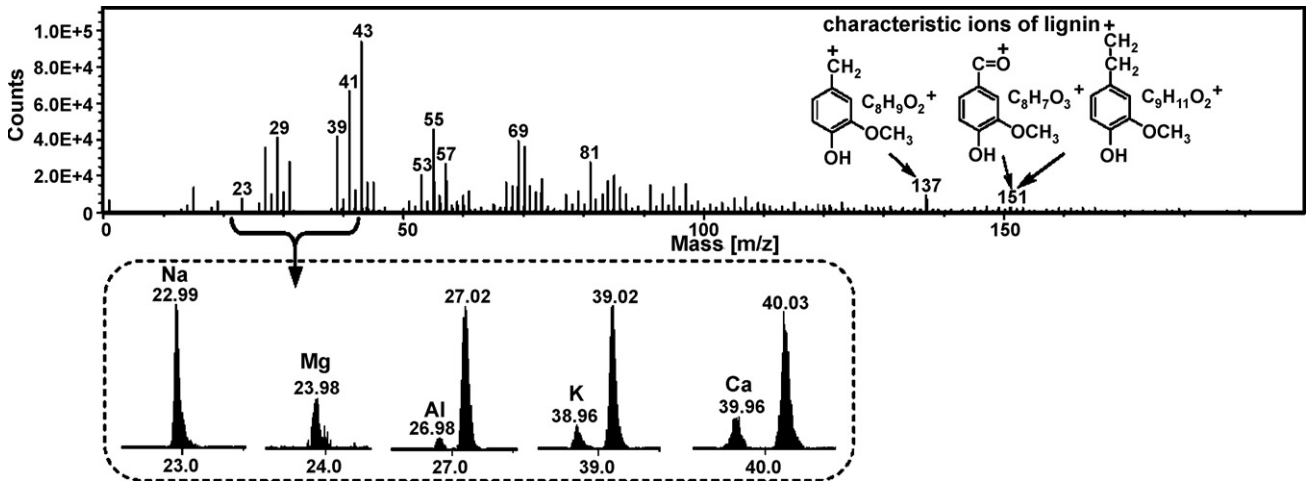

Fig. 2. Positive ToF-SIMS spectrum of the transverse section of Hinoki cypress. The spectrum is obtained from the ring S4 in sapwood. The figure also shows expanded portions of the peaks from each element, Na, Mg, Al, K, and Ca.

elements in the transition zone between sapwood and heartwood, which is clearly distinguishable by white colour in the freeze-preserved sample. The distribution of lignin polymer was also investigated using the characteristic monomeric ions with a substituted aromatic ring (guaiacyl ring), which were recently identified by ToF-SIMS [8].

2. Materials and methods

2.1. Materials

A 31-year-old Hinoki cypress (*C. obtusa*, gymnosperm) tree was cut in the summer of 2005 in Nagoya University Forest, Inabu,

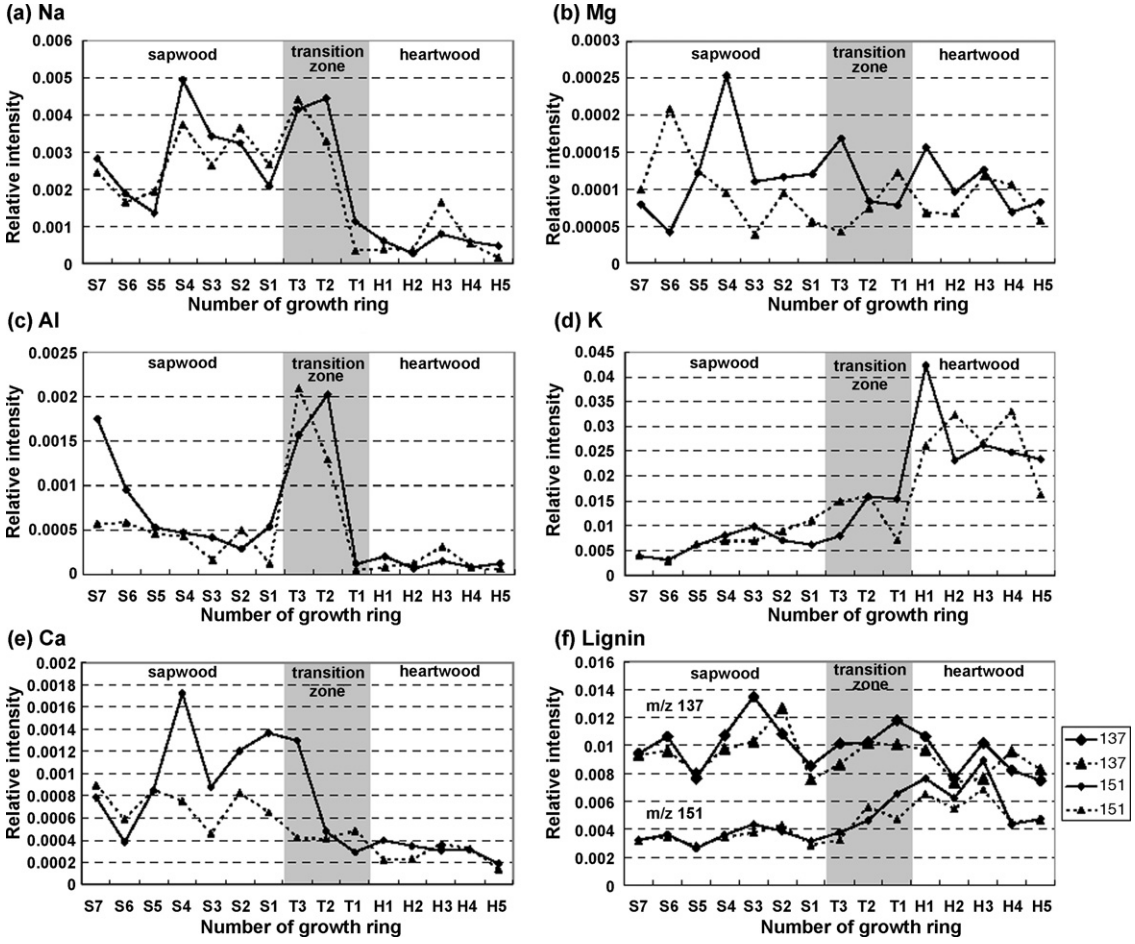

Fig. 3. The distribution of relative intensities of the ions derived from (a–e) elements, Na, Mg, Al, K, and Ca, and (f) lignin, in the contiguous growth rings ranging from sapwood to heartwood (S7–H5) in Hinoki cypress. Data were obtained from two positions (solid and dotted lines) in each growth ring. The gray shading shows the transition zone between sapwood and heartwood.