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ANATOMICAL ANALYSIS OF NATURAL AND THERMALLY MODIFIED WOOD

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ABSTRACT

Thermally modified wood is a unique natural material with special properties, that have been received after heat treatment of natural wood. All these properties are the result of changes in the chemical composition and structure of the wood. The paper aims to identify gaps in the structure of natural and thermally modified wood. The changes in the structure of the wood after its heat treatment were discussed.

We examined the specimens of pine, spruce, summer oak, hornbeam and birch wood. Microscopic preparations were made from the wood specimens before and after heat treatment. The three main sections of wood at different zoom were observed. There have been noticed differences in the construction of anatomical elements.

Key words: thermally modified wood, pine, spruce, oak, birch, hornbeam, microscopic analysis.

Properties and methods for thermal modification of wood have been studied in detail. Moreover, some detail in the explanation of the changes in the structure of wood afterheat treatment are missing.

It is very important the examination of wood to be with the help of light microscope. Only this technology provides an opportunity to investigate the cell walls and their modifications in detail. This is the only way all deformations, folds, cracks, etc. can be seen. The main problem here is to distinguish between the deformations and fractures obtained in making microscopic samples, of those obtained by heat treatment.

The aim of this study is to confirm or reject the changes in the anatomical structure of wood after thermal modification.

METHODS AND MATERIALS

The wood of Scots pine (*Pinussylvestris* L.), Spruce (*Piceaabies* Karst.), Pedunculate oak (*Quercusrobur* L.), White birch (*Betulapendula* Roth.), Hornbeam (*Carpinusbetulus* L.) is studied. Thermally modified wood is obtained under the following conditions.

The pine, oak and hornbeam wood specimens used in this study were obtained in Litin, Vinnitskaya region, Ukraine (Vladimirova, 2012). The birch and spruce were obtained in smtOzerki, Tverskaya region, Russia (Vladimirova, 2011). Prior to thermal modification, the boards have already been kiln-dried. After that the pine, oak and hornbeam boards were treated in thermoconvectiveheat treatment dryer (Russian name – SPCT, Fig. 1, left) and birch and spruce boards were treated in vacuumheat treatment dryer (Russian name – SPVT, Fig. 1, right) both from Russian company “Vacuumplus” using various schedules. The dryers work on four temperature categories: A = 165 °C; B = 175 °C; C = 185 °C; D = 195 °C. The properties of the boards and key treatment parameters are presented in Table 1.

Figure 1: The thermoconvective – SPCT (left) and vacuum – SPVT (right) heat treatment dryer.

Table 1: Summary of the boards' properties and treatment conditions

Species	Number of trunks	Log dimension		Number of boards	Initial average MC [%]	Boards dimension [mm]	Maximum temperature [°C]	Total processing time, [h]	Duration at maximum temperature [h]
		Diameter [cm]	length [m]						
Pine	30	32–34	4.5	30	6-8	4000x200x50	165	72	12
Spruce	25	32–34	4.0	25	6-8	4000x200x50	165	72	12
Birch	25	32–34	4.0	25	6-8	4000x200x50	185	72	12
Oak	10	22–24	2.5	10	6-8	2500x140x35	175	72	12
Hornbeam	25	22–24	2.5	25	6-8	2500x140x35	175	72	12

After the heat treatment, the boards were visually evaluated for twists, cracks and other deformations. The untreated wood of the same species was used as a control.

The boards were visually checked after they were taken out of the dryer. The visible defects were found to be at minimum level. The overall performance of boards was quite acceptable.

Specimens with dimensions 20x20x 30 mm were prepared from the part of the boards. The first part of the tested wood is intended for microscopic examination, and the second one - for thermal modification. From both parts were made microscopic samples. In consequence, the same wood can be observed before and after the heat treatment. The wood was soaked in glycerin for one year. This led to softening. Preparing thinner sections was possible. Photos were taken of the three sections of the tested wood. Anatomical elements were observed in optical zooms x32, x100 and x400. The differences between natural and thermally modified wood were compared.

RESULTS AND DISCUSSION

Spruce (*Picea abies* Karst.)

The annual rings are clearly delimited, regular and medium-wide. The tracheids of natural wood have rounded polygonal shape, but after the heat treatment become more rounded (Fig. 2). At high microscopic zoom are clearly visible the primary and secondary cell walls.

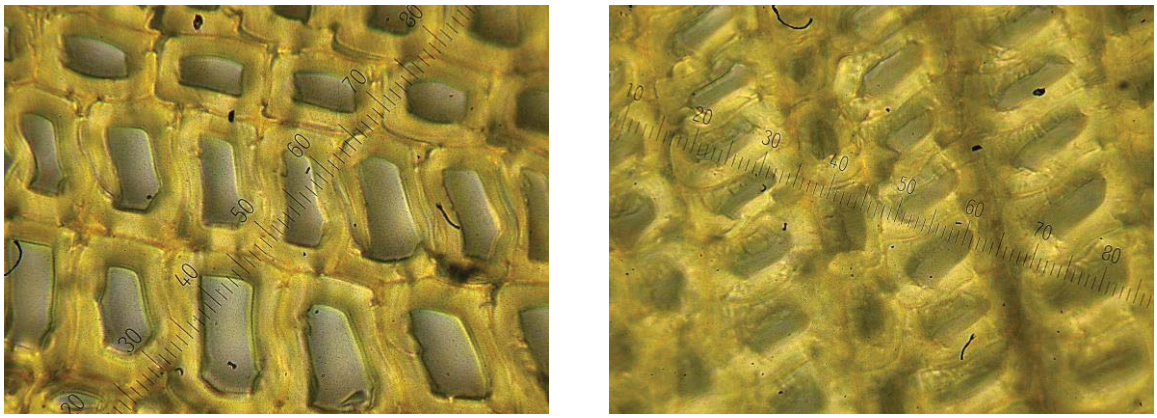

Figure 2: Cross section (x400) of natural (left) and thermally modified wood of spruce (right).

In thermally modified wood are observed typical transversal lines in the cell wall. They are probably micro cracks, which explain the lower mechanical properties of this type of wood. There are well-formed small resin canals, which after the heat treatment are highly fragmented. On the walls of the tracheids in cross section are not observed fragments, which abound in longitudinal section. The cells of single-row core rays are highly fragmented, while those of spindle rays are unaffected (Fig. 3).

In the radial sections of many of the photos are observed typical injuries. Probably these are the folds of the S_3-layer of the secondary cell wall. Very often on the cell walls are observed strongly tilted thin lines. They resemble an increase of the size of the helical structure of the cell wall, which normally absent in natural spruce wood. This probably indicates a separation of the secondary cell wall.

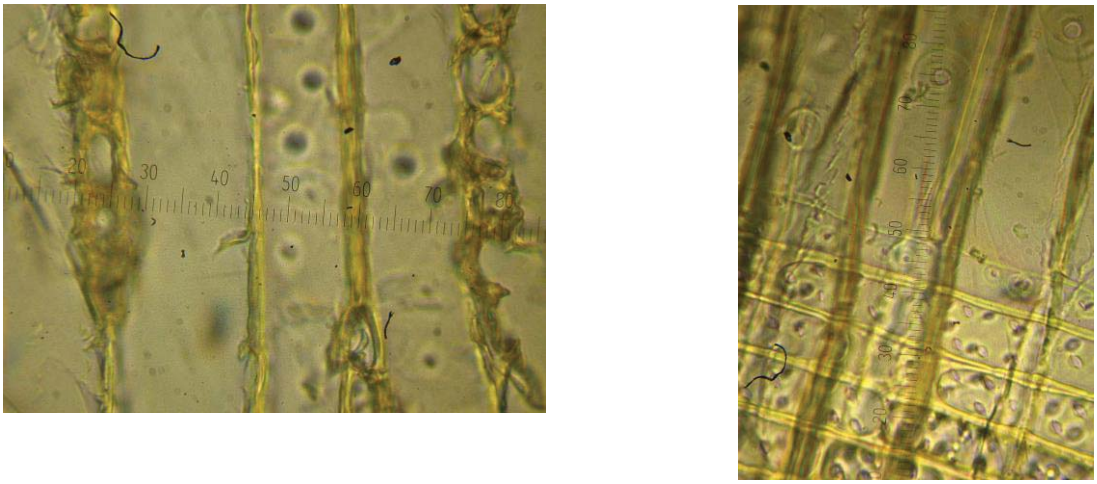

Figure 3: Core rays and mechanical cells in a tangential section (left) and a radial section (right) of a thermally modified wood of spruce, x400.

The cell walls of parenchymal cells are well formed. Neither in them, nor in the tracheids are observed fillers. There are not observed any destruction or blockage of pores.

Scots pine (*Pinus silvestris* L.).

The annual rings are unaffected and well formed. Late wood makes it difficult to pre-

pare the microscopic samples of the thermally modified wood (Fig. 4). After the heat treatment the tracheids become more rounded, which is better illustrated in late wood. The fragmentations of the cell wall have probably been obtained during the preparation of the sample.

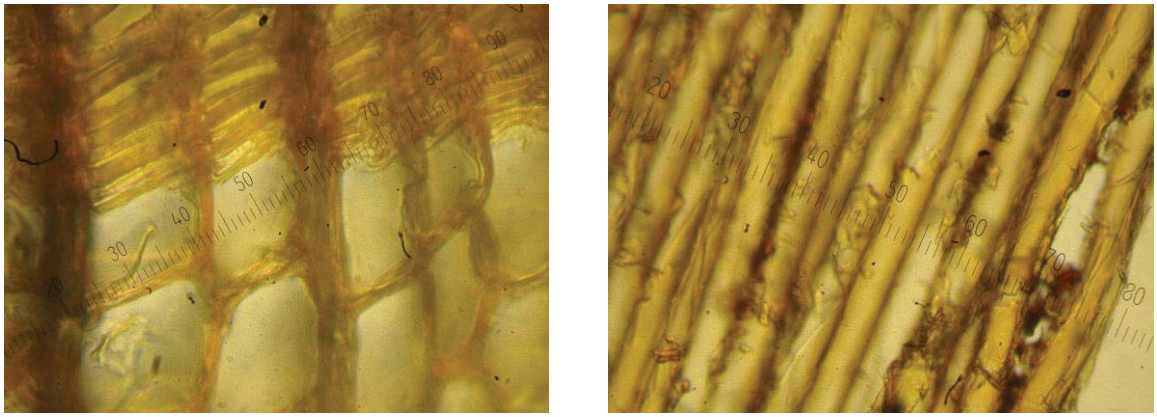

Figure 4: Cross (left, x400) and tangential (right, x100) section of thermally modified pine wood.

There are no cracking or fragmentations of the cell wall. Here are not visible separately the primary and secondary cell walls. In longitudinal sections are observed many fragmentations (Fig. 4). They may be caused during the preparation of the sample, but are missing in natural wood. The resin canals are heavily damaged, but this is typical of pine wood.

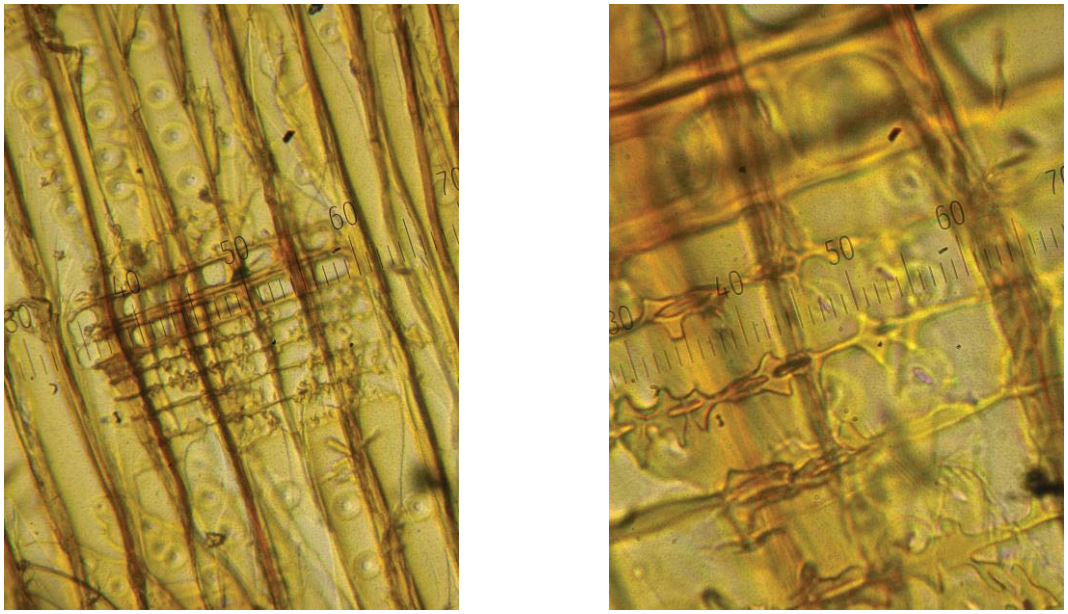

Figure 5: Core rays and traheids in radial section of thermally modified pine wood with optical zoom x100 (left) and x400 (right).

It is interesting to see the indentation of the structure of the inner wall of the parenchymal cells (Fig. 5). After heat treatment they have preserved their typical sharp shape. It is likely that they are located away from the knife, so as to have no contact with it during the preparation of the samples. Therefore, it

can be argued that after the heat treatment the shape of the cell walls does not change.

In pine did not occur the separation of the layers, which occurred in spruce. Here are also not observed any destructions and blockage of pores. Nor in the parenchymal cells or in the tracheids are observed fillers.

Oak (*Quercus robur* L.)

In the oak structure there is a great difference in the location of the conductive and mechanical tissues in the early and late wood (Fig. 6). The late wood in the microscopic samples is thick, while the early wood – is destroyed. Wood parenchyma is hardly visible, but after the heat treatment it becomes clearly indicated.

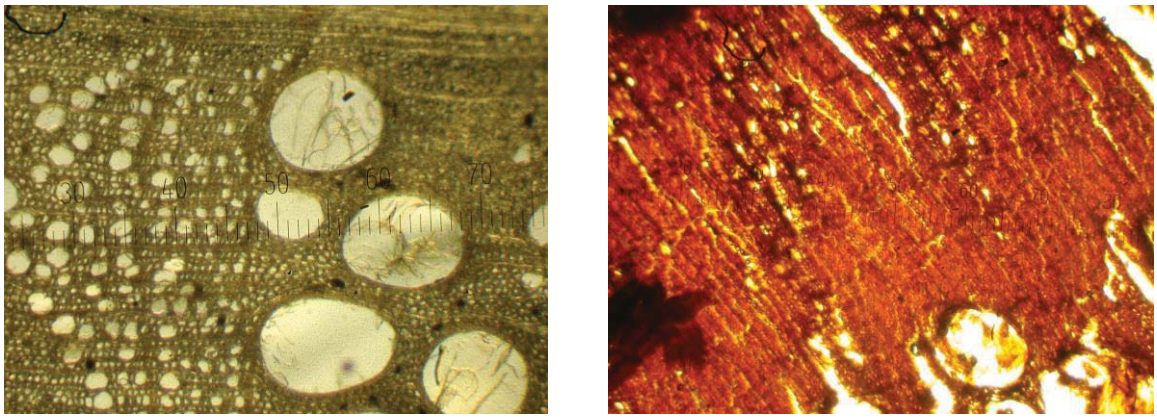

Figure .6: Cross section (x32) of natural oak wood (left) and after heat treatment (right).

After the heat treatment the vessels have heavily damaged walls. The tiloids and the nearby mechanical cells are also damaged. The late small tracheas are less affected.

The cells which build up the core beam are round, with thick walls, often filled with a brown substance, even in natural wood (Fig. 7). It is important that after the heat treatment the broad rays' cells are much darker and deformed than the single row's ones.

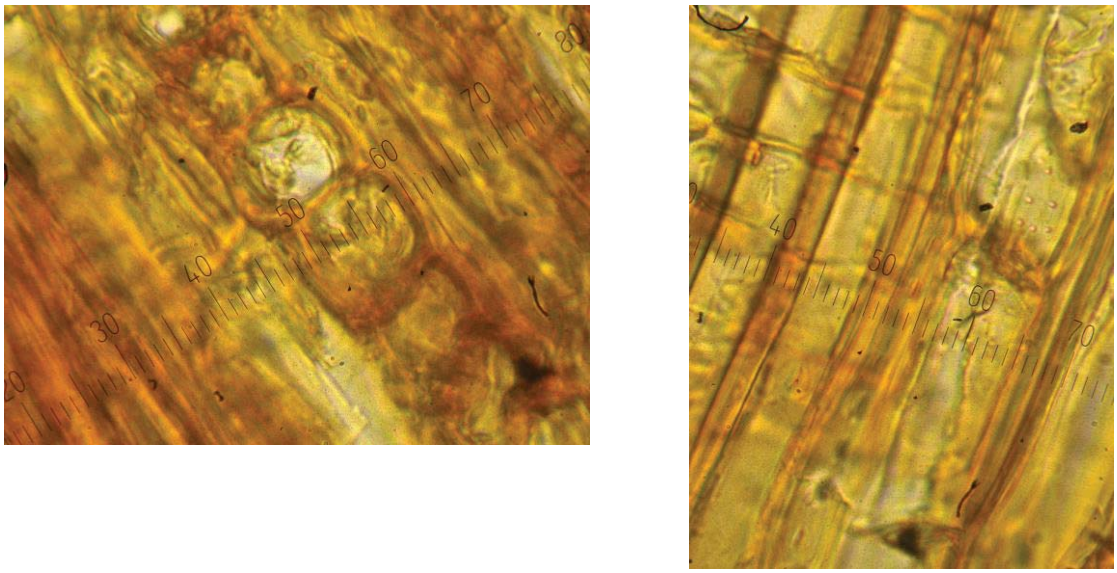

Figure 7: Core rays and mechanical cells in tangential section(left)and vessels, fibers and rays in radial section (right) of thermally modified oak wood with optical zoomx400.

The pores on the walls of the vessels are reserved and opened. There is no deformation or destruction. In all cells is noticeably the accumulation of cell walls, probably due to the thickness of the samples.

Hornbeam (*Carpinus betulus* L.)

After the heat treatment of the hornbeam, the borders between the annual rings become more clearly visible. The mechanical tissue is made of thick-walled cells. After the heat treatment they enhance the difference between early and late wood (Fig. 8). Wood parenchyma has little presence, but after the treatment can be seen better than in natural wood.

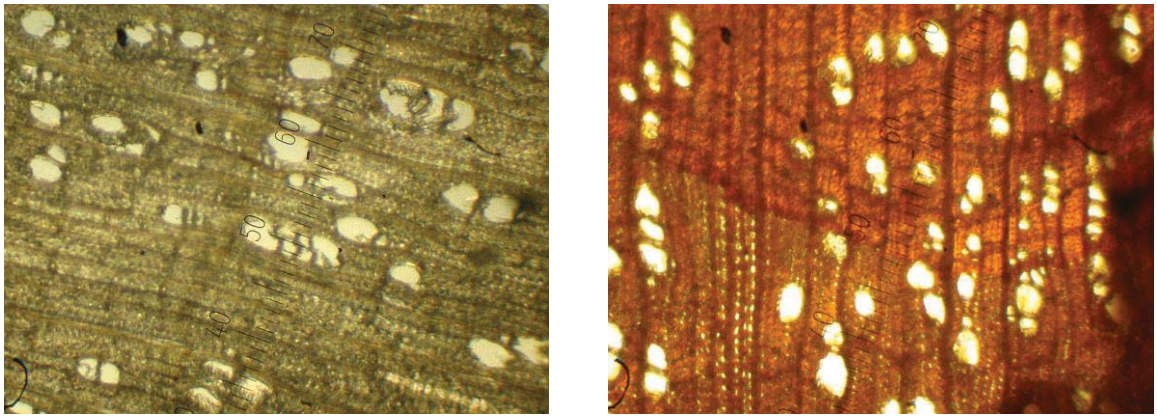

Figure 8: Cross section (with optical zoomx32) of natural hornbeam wood (left) and thermally modified (right).

After the heat treatment the walls of the vessels are heavily damaged. It can be considered that this is the S_3-layer, because on all of the photos it is seen as a translucent skin. The destruction covers almost all of the walls where vessels are gathered into groups.

A measuring of the dimensions of the mechanical cells shows slight differences after the treatment. The average diameter is a little larger, which changes the area of the cell walls and the cell gaps. Thus the stenosity in natural wood is about 1.14, while in thermally modified wood is 0.89 (Fig. 9).

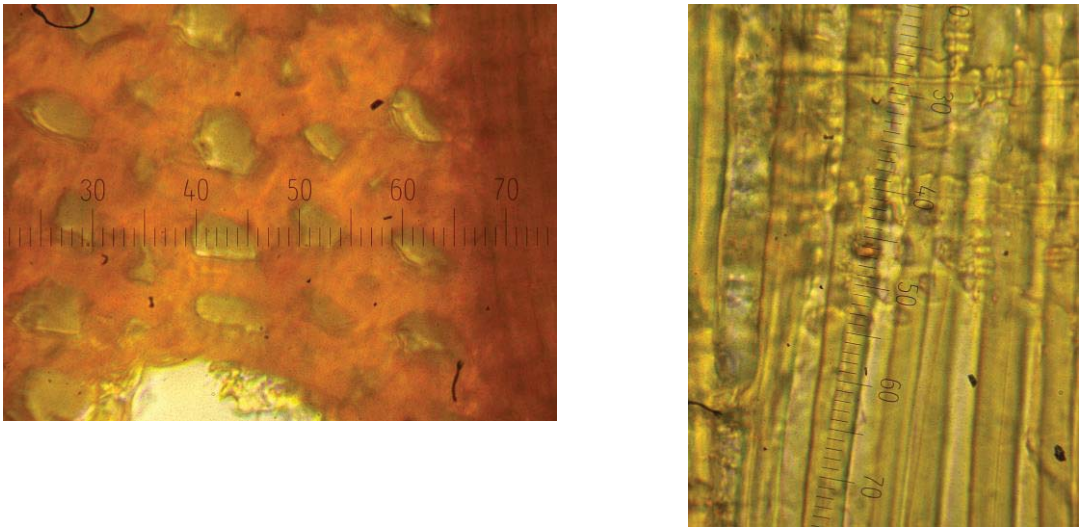

Figure 9: Crosssection of thermally modified hornbeam wood (left) and radial section (right) x400

In cross section and small optical zoom, the rays resemble small dark lines. The average cells of the rays are oval, the top and bottom cells of the rays are elliptical, but all of them are highly fragmented and filled with dark brown substance.

The pores are not blocked or damaged (Fig. 9). The thickenings on the spiral structure of the vessels are preserved without damage. In all parenchymal cells there is bright orange-brown substance.

Birch (*Betula pendula* Roth.)

The border between the annual rings in the natural wood of the birch is not well defined as well as in the thermally modified wood (Fig. 10). Despite the fact that the core rays are narrow, they are clearly visible. The wood parenchyma is not visible nor in the natural or in thermally modified wood.

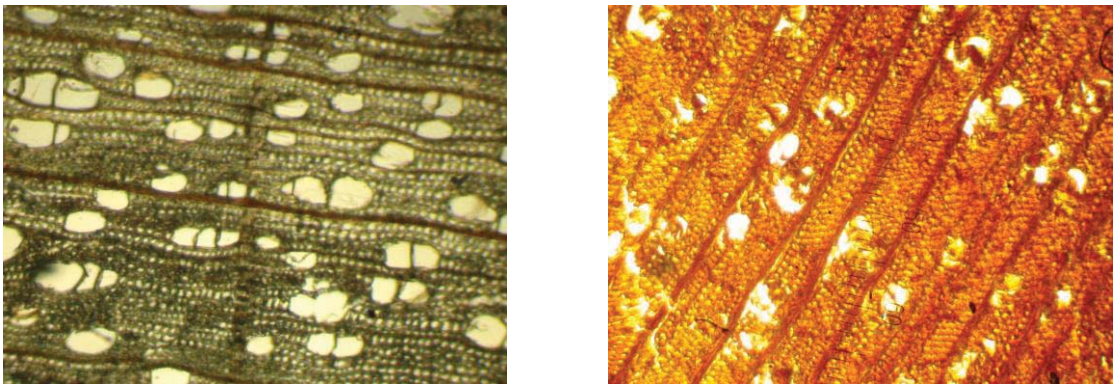

Figure 10: Cross section of a natural birch wood (left) and thermally modified wood (right) with optical zoom x32.

After the heat treatment the vessels' walls are highly damaged. The fragmentation covers and the nearby mechanical cells. Probably the heat treatment highly worsens the connections between the cells. This is the reason why the preparation of a microscopic sample in cross section was very difficult. In contrast to the hornbeam the birch increased its stenosity after the heat treatment. It is often observed rupture of the boundary layer between the core rays and mechanical cells. The cells are highly fragmented but is not observed filling.

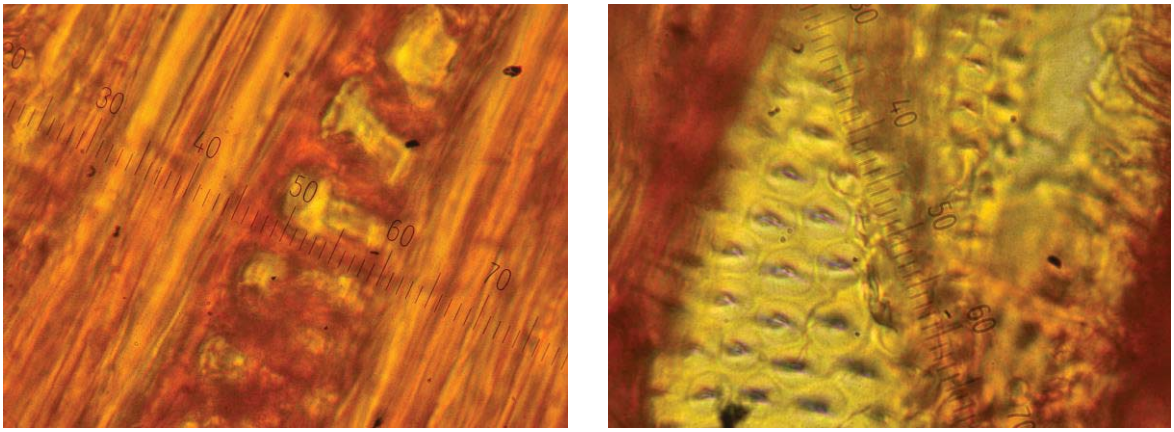

Figure 11: Core rays and mechanical cells in tangential section (left) and vessels in radial section (right) of thermally modified birch wood with optical zoom x400.

The pores on the walls of the vessels are reserved and opened. In natural wood in radial section it is clearly visible perforations in the form of steps. It is not clear whether the damages of this perforation are a result of preparing the sample, or the heat treatment. Neither in the parenchymal cells, nor in the vessels is observed fillers.

CONCLUSION

- The preparation of the microscopic samples is very difficult, because the thermally modified wood becomes very crushable;
- In cross section in the conifers is observed rounding of the shapes of the cells, while in longitudinal sections are retained the pointed forms.
- All microscopic samples of oak and birch in cross section were obtained thick and strongly deformed.
- The micro cracks, which are visible in the spruce wood are not observed in other species.
- No change occurred in the modifications of the cell wall, which proved the preservation of the structure of the cellulose after the heat treatment.
- When making future research it is necessary to take into account the connection between the operating modes of heat treatment and the stenosity of the cells.

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