THERMAL MODIFICATON OF SPRUCE TONEWOOD

Pacific Rim Tonewoods
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The wood of the spruce tree (genus *Picea*) is prized for its acoustic properties, and has been used since late 1600's for the soundboards and bracing of stringed instruments. The acoustic properties of spruce wood arise out of its unique physical characteristics: High stiffness, low density, and low internal friction (aka damping). These acoustic properties allow for an efficient transfer of sound to the vibrating strings, and a clear, resonant sound.

These acoustic properties can be improved by thermal modification. Thermal modification refers to the application of heat in the absence of oxygen. Under the right circumstances, stiffness can be increased, and density and damping can be decreased -- permanently and reliably.

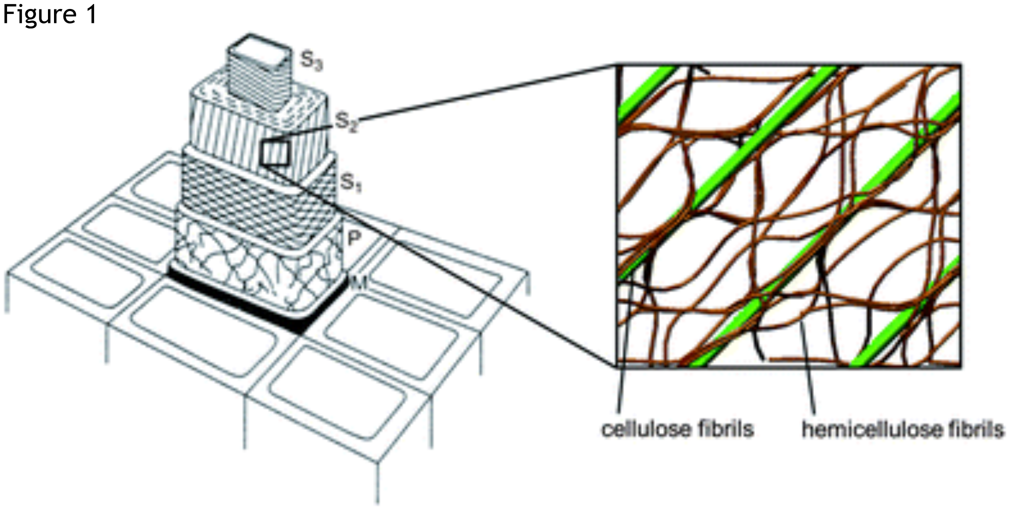
There are many techniques for thermal modification, many different names, and many different end uses. To clear up some of the understandable confusion, we have produced this short primer on thermal modification of spruce wood.

THE ANATOMY OF WOOD

The basic building block of all wood is a specialized plant cell known as a tracheid, a long thin hollow cell about the width of a fine human hair. These tracheids, billions of them in a typical old growth tree, are bunched together in a structure that resembles a microscopic bundle of straws, oriented along the axis of a tree. These "bundles" are what gives wood its tremendous strength.

If we look closer at each of these tracheids, we find that the walls of these hollow tracheids are composed of strong fibers of cellulose, surrounded by a "starchy" substance known as hemicellulose (see Figure 1). Cellulose has been compared to rebar (cellulose) running though and strengthening the concrete (hemicellulose). The cellulose and hemicellulose are bonded to one another by relatively weaks bonds known as hydrogen bonds, which use a molecule of water as a type of adhesive. Even though the individual hydrogen bonds are relatively weak, the overall structure is incredibly strong.

Figure 1



## HOW DOES THERMAL MODIFICATON WORK?

Thermal modification works primarily on hemicellulose, and the hydrogen bonds between hemicellulose and cellulose. If we heat wood for a number of hours to about 350 degrees Farenheit, in the absence of oxygen, some of the hemicellulose will degrade, and some of the water will be driven from the weak hydrogen bonds, converting these to a stronger covalent bond. If you have read about "cross linking" with thermal modification, this is primarily what is meant.

## WHAT EFFECTS DOES THIS HAVE ON THE PROPERTIES OF THE WOOD?

1) Density **decreases**: Primarily due to the partial loss of hemicellulose. Most studies show that 5 – 8 % of the hemicellulose can be lost without sacrificing too much strength or structure.

2) Stiffness **increases**: The replacement of hydrogen bonds with covalent bonds between hemicellulose and cellulose increases stiffness, especially "across the grain" of the wood. One potential downside to this is that the wood also becomes more brittle.

3) Moisture Content **decreases**: All wood will absorb atmospheric moisture, proportional to relative humidity. The ability of wood to absorb moisture is decreased in thermally modified wood, because of the partial loss of the hydrogen bonds. Thus, not only will thermally modified wood have lower moisture content at a given relative humidity, but that wood will be less susceptible to swelling and shrinking with changes in relative humidity.

4) Damping **decreases**: Damping, or internal friction, refers to the speed with which a vibration returns to zero. For example, a car's shock absorber has high damping, a brass bell has very low damping. In wood, damping is strongly dependent upon moisture content. High moisture increases damping, and dry conditions decrease damping. Thermally modified wood will always have lower moisture content than natural wood at a given relative humidity, and thus that wood will have lower damping.

## WHAT DOES THIS ALL MEAN FOR TONE?

Two guitars side by side, identical but for soundboards made of thermally modified vs natural wood, would produce different tone. The thermally modified top will be slightly lower in density, and slightly stiffer across the grain because of intrinsic changes in the wood induced by the modification. It will also have lower damping as a result of lower moisture content. All other things being equal, this would result in a guitar with greater responsiveness, louder average volume, and slightly greater sustain.

## IS THERE A DOWN SIDE?

Thermal modification can be easily "overdone", with either higher temperatures or with longer treatment times, resulting in wood that loses stiffness and strength. Even in the best of circumstances, thermally modified wood is more "brittle" or susceptible to cracking and fracture. Pacific Rim Tonewoods is currently conducting research on all aspects, good and bad, of thermal modification, with one of the leading experts in this field, Professor Alexander Pfriem of Berlin, Germany. Through this research, the first of its kind, we are comparing the various methods of thermal modification, and optimizing the "recipe". In so doing, we are increasing the quality, consistency, and reliability of the thermally modified spruce that we supply to the acoustic guitar community.