Chemical analysis reveals the hidden secrets of Stradivari violins

NTU researchers identified unique properties in the wood of famous antique instruments

The secrets of Stradivari violins are one of the most enduring mysteries of European culture. Antonio Stradivari (1644-1737), Latinized as "Stradivarius" and abbreviated "Strad," has become synonymous with superlative violins. What gives his violins such unique tonal qualities has been a matter of heated debate over the past two centuries.

The legend of Stradivari began in Cremona, a small Italian town that witnessed the invention of the modern violin almost 500 years ago. Most experts agree that the excellence of Stradivari violins remains unsurpassed and that Stradivari possessed certain "lost secrets." However, there are different opinions about the nature of these secrets. By collecting wood shavings from Stradivari violins during restorations and subjecting them to modern chemical analyses, a team of three NTU chemistry professors, Hwan-Ching Tai, Jerry Chun Chung Chen, and Hao Ming Chen, has demonstrated that the maple wood used by Stradivari has different chemical properties than the maple used to makemodern violins. Their recent study [1] was picked up by over 100 international media outlets, including *The New York Times, The Washington Post, The Times, and Yomiuri Shimbun*.

Previously, many experts regarded the lost varnish recipe as Stradivari's grand secret. This notion was made popular by the movie *The Red Violin*, which fictionally depicted human blood as the secret varnish ingredient. After decades of scientific investigations into Stradivari's varnish composition, there is little evidence to suggest that Stradivari's formulation carried extraordinary acoustical properties, although its visual beauty remains unmatched. Instead, the violin world has gradually turned its attention to the unique properties of the wood of Stradivari violins [2].

With the assistance of international violin experts and Chimei Museum, which owns the world's largest collection of antique Italian violins, Professor Tai acquired maple specimens from four Strad instruments. Nuclear magnetic resonance spectroscopy revealed that Stradivari's maple exhibited hemicellulose degradation; approximately one-third of the hemicellulose had degraded in the past 300 years. Hemicellulose is the most hygroscopic fiber component in wood, and its degradation leads to reduced moisture absorption and reduced internal damping, allowing the wood to vibrate more freely. Second, elemental analyses showed that Stradivari's maple appeared to have been infused with salts of sodium, potassium, and calcium, as well as alum, borax, zinc sulfate, and copper sulfate. A combination of these minerals was probably used for "salt seasoning" and biocidal protection against fungi and worms and may promote the chemical crosslinking of wood fibers. Stradivari's chemical treatments were completely unknown to later European instrument makers, whose standard practice was to make instruments out of air-dried wood.

Third, maple from Stradivari violins and cellos showed remarkable differences in their molecular architectures. When wood samples were gradually heated to 600 °C, there was an extra peak in the heat release curve of Stradivari violins, which was absent in the curves of Stradivari cello and natural maple samples. The extra peak suggested reduced molecular adhesion between the cellulose and lignin in the wood, likely caused by the high frequency vibrations created while playing the violin.

Hence, the chemical distinctions between Stradivari's maple (in its current state) compared to modern maple can be attributed to three factors: initial chemical treatment, age-dependent chemical decomposition, and molecular rearrangement due to long-term vibrations. Professor Tai's findings may help explain why it has been so difficult to reproduce the acoustic properties of Stradivari violins using modern wood.

References

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2. Joseph Nagyvary, Joseph A. DiVerdi, Noel L. Owen and H. Dennis Tolley, (2006). Wood used by Stradivari and Guarneri. *Nature* 444, 565. DOI:10.1038/444565a.

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Figure 1. Maple back plate and maple rib on the 1709 "Marie Hall-Viotti" Stradivari violin, courtesy of Chimei Museum.

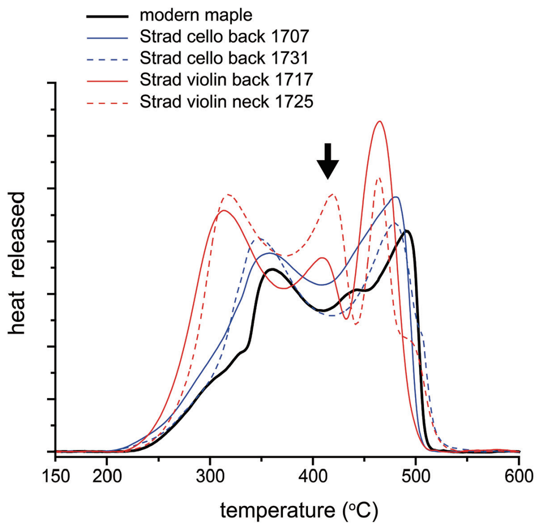

Figure 2. Wood heat release curves of Stradivari violins differ from those of Stradivari cellos.

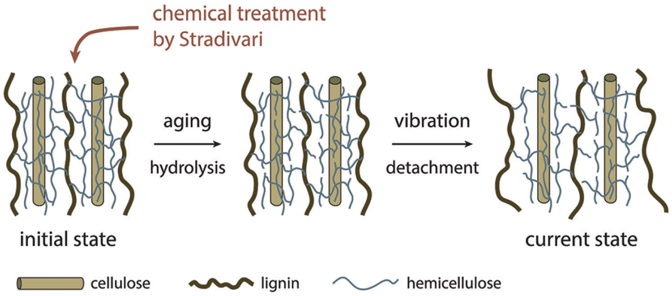

Figure 3. The effects of chemical treatment and aging on Stradivari's wood.