Synchrotron radiation micro-computed tomography for the investigation of finishing treatments in historical bowed string instruments

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Elettra: SYRMEP

Coating systems in historical bowed string instruments are often multi-layered structures combining several inorganic and organic materials. The experiments performed at the SYRMEP beamline aimed at testing the still unexplored application of micro-CT (micro Computed Tomography) for the investigation of these systems. The experimental settings were optimized for the detection of the main features expected. Two sets of mock-ups and a fragment removed from a cello by Andrea Guarneri were then scanned obtaining impressive images of the most relevant features of the layered structures.

During the last decades, scientists have proposed many procedures for the identification of methods and characterization of materials used in the past by violin-making Masters. Nowadays, integrated multi-analytical approaches are used to investigate historical bowed string instruments, with focus on describing the complexity of their multi-layered coating systems. Micro-invasive analyses are widely used for getting an in-depth characterization of materials, but they need a small piece to be detached for the analyses, and sampling on precious ancient musical instruments shall represent an exception, and not a common procedure for scientific tests. The use of non-invasive analytical protocols is increasingly becoming the selected choice, with micro-tomographic techniques certainly playing a prominent role. The application of micro-CT to the investigation of coating systems in historical bowed string instruments is presently rare.
In this research we aimed at enriching the knowledge about the stratigraphic morphological features of the finishing layers of ancient Master focusing on a fragment detached from a cello attributed to Andrea Guarneri. The task was faced by using a set of analytical

Figure 1: Tomographic setup of the high-resolution SR-micro-CT in phase-contrast mode at the SYRMEP beamline at Elettra.

techniques, according to both non-invasive and micro-invasive approaches. Among the many techniques that have been employed to investigate the fragment, a collaboration was set between the Arvedi Laboratory in Cremona and the Chemistry and Physics Departments of the University of Torino, who got access to the SYRMEP micro-CT beamline, setting up the conditions in order to achieve the highest spatial resolution technically permitted (1 μm^2) for micro-CT scans at the facility (Fig. 1). This first goal was achieved by scanning several mock-ups prepared in the lab by mimicking the finishing layers of a bowed string instrument, in order to select the best procedures and set-up (Fig. 2).
After that, the fragment of the ancient cello was considered and the team obtained impressive high-resolution tomographic 3D models of the stratigraphy of the fragment under examination. Previously obtained results on the chemical characterization of the layered structures were considered in order to broaden the information and support the interpretation of the micro-CT images with compositional data, thus meeting the ambitious goal of building-up a high-resolution 3D description of the finishing layers.
The slices highlighted the presence of a ground coat penetrating into the wood porosity for some 200 µm, and embedding inorganic particles which were also detected. A varnish layer is then spread on the ground coat, and contains fine particles (previously identified as red ochre), barely detectable due to their low concentration and very small diameter (about 2 µm).
The most beneficial aspect of synchrotron radiation micro-tomographic approach in the investigation of complex layered structures of historical instruments is related to the possibility of obtaining a high-resolution picture of materials even if they are almost transparent to x-rays. For these materials, as for examples the organic ones, conventional microtomographic sources do not have suitable intensity and spatial coherence to exploit the phase-contrast effects, which has been crucial in the investigation of the cello fragment. The presence - or the lack - of a preparation layer, the position of the particles in each layer, the different grain size distributions are valuable information for a preliminary characterization of the musical instrument. All these features have been highlighted though the developed procedures at the Synchrotron Radiation micro-CT. 3D virtual representations that have been obtained have merits as they enable to highlight the main morphological features of the overlapping layers even describing the distribution of tiny particles in low concentration. Together with further new non-invasive results concerning the composition of the ground layer and of the organic substances employed in the varnishes, we will be soon able to give a new point of view on the finishing techniques of ancient violin making art.

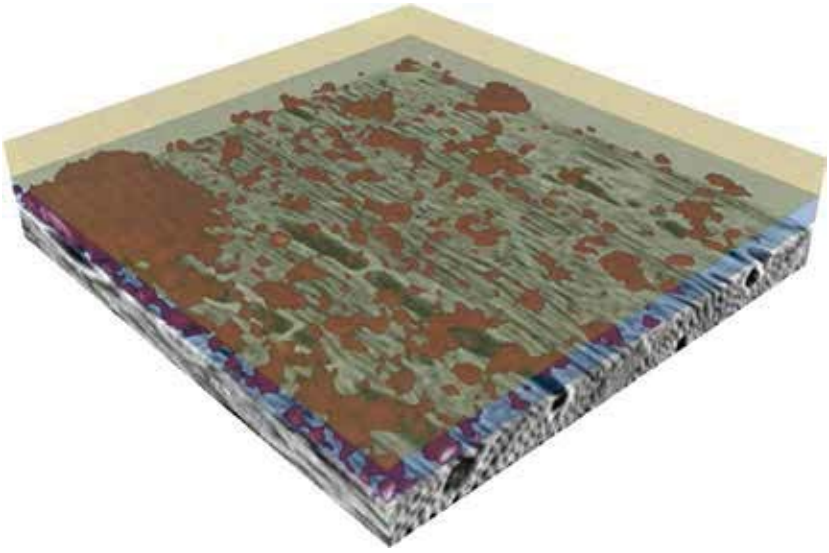

Figure 2: Virtual reconstruction of the coating system on a mock-up prepared on maple wood (grey) with gypsum particles (red) dispersed in a proteinaceous preparation layer (blue) covered with a linseed oil-colophony varnish (yellow).

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Original paper

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