3D-printed material to replace ivory for restoration of artifacts

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On the right: The new material Digory; ivory on the left. Credit: Vienna University of Technology

For centuries, ivory was often used to make art objects. But to protect elephant populations, the ivory trade was banned internationally in 1989. To restore ivory parts of old art objects, one must therefore resort to substitute materials—such as bones, shells or plastic. However, there has not been a really satisfactory solution so far.

TU Wien (Vienna) and the 3D printing company Cubicure GmbH, created as a spin-off of TU Wien, have now developed a high-tech substitute in cooperation with the Archdiocese of Vienna's Department for the Care of Art and Monuments and Addison Restoration: the novel material "Digory" consists of synthetic resin and calcium phosphate particles. It is processed in a hot, liquid state and hardened in the 3D printer with UV rays, exactly in the desired shape. It can then be polished and color-matched to create a deceptively authentic-looking ivory substitute.

Beautiful and Mechanically Stable

"The research project began with a valuable 17th-century state casket in the parish church of Mauerbach," says Prof. Jürgen Stampfl from the Institute of Materials Science and Technology at TU Wien. "It is decorated with small ivory ornaments, some of which have been lost over time. The question was whether they could be replaced with 3D printing technology."

The team already had experience with similar materials: the research group also works with ceramic materials for dental technology, for example. Nevertheless, it was a challenging task to develop a suitable

substitute for ivory: "We had to fulfill a whole range of requirements at the same time," says Thaddäa Rath, who worked on the project as part of her dissertation. "The material should not only look like ivory, the strength and stiffness must also be right, and the material should be machinable."

Stereolithography in the 3D printer

Through numerous experiments, Thaddäa Rath and other members of the team from TU Wien and Cubicure succeeded in finding the right mixture: Tiny calcium phosphate particles with an average diameter of about 7 µm were embedded in a special resin, together with extremely fine silicon oxide powder. The mixture is then processed at high heat in Cubicure's 3D printers using the hot lithography process: Layer by layer, the material is cured with a UV laser until the complete object is finished.

"You also have to bear in mind that ivory is translucent," explains Thaddäa Rath. "Only if you use the right amount of calcium phosphate will the material have the same translucent properties as ivory." Afterwards, the color of the object can be touched up—the team achieved good results with black tea. The characteristic dark lines that normally run through ivory can also be applied afterwards with high precision.

No more tusks!

In the field of restoration, this is a big step forward: With the new material "Digory," not only is a better, more beautiful and easier to work with substitute for ivory available than before, the 3D technology also makes it possible to reproduce the finest details automatically. Instead of painstakingly carving them out of ivory substitute material, objects can

now be printed in a matter of hours.

"With our specially developed 3D printing systems, we process different material formulations for completely different areas of application, but this project was also something new for us," says Konstanze Seidler from Cubicure. "In any case, it is further proof of how diverse the possible applications of stereolithography are."

The team hopes that the new material "Digory" will become generally accepted in the future—as an aesthetically and mechanically high-quality ivory substitute, for which no elephant has to lose a tusk.

More information: Thaddäa Rath et al. Developing an ivory-like material for stereolithography-based additive manufacturing, *Applied Materials Today* (2021). DOI: 10.1016/j.apmt.2021.101016

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