When Rapid Prototyping meets Electrochemistry

The PLECO: an electrolytic pencil for the localised cleaning of tarnished silver & gilded silver

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Abstract

The aim of this paper is to give a quick overview of rapid prototyping possibilities in the conservation of cultural heritage. This technology enables the manufacturing of complicated elements or objects using 3D printing in combination with laser cutting, etc. It might seem expensive and rather inaccessible but today specialised laboratories, named FabLabs, offer such equipment for renting at low cost. After introducing some possibilities of using the rapid prototyping and FabLab technologies applied to cultural heritage, this paper will present a special conservation tool that has been recently designed and fabricated in a FabLab – The PLECO. The PLECO is an electrolytic pencil used for the localised cleaning of tarnished silver and gilded silver composite artefacts combined with inseparable elements (for example wood, enamels or precious stones). It has been developed by the University of Applied Science – Arc and its conservation division (HE-Arc CR) in partnership with the University of Applied Science – Arc and one of its engineering division, the Edana Laboratory (EDANA). As an outcome of the “Saint-Maurice” research project it enabled the cleaning of some of the composite masterpieces of the Treasury of Saint-Maurice abbey before their installation in a new exhibition hall for the Jubilee (1500 years) of the creation of the Abbey in 2015.

Rapid Prototyping & the Fablabs

State of Art

At the beginning of the 21th century rapid prototyping technology and more particularly 3D printing are blowing up. Everyday new use of these technologies can be seen in unexpected domains. Low-cost prosthesis[1] are currently developed in the medical field and in a near future it will be possible to print human tissue and organs[2]. Similarly the European Space Agency (ESA) works on a giant 3D printer to build a lunar base using only salted water and the sand available in the moon soil[3]. Artists and designers are important users of 3D printing. Because of the reduction of manufacturing constraint, this technology accompanies their creativity and gives them more freedom.

For most applications mentioned above the use of expensive and large printers is required. The cost is a major issue in the dissemination of a new technology, particularly in the conservation field. Fortunately many new developments are occurring in this domain because of the presence of a large, pro-active and networked community of professionals. Low cost does not mean low technology and the use of such 3D devices enables the conservator to count on 0.1mm precision for a basic printer.

The FabLabs

As suggested by its name, a FabLab is a fabrication laboratory. More precisely it is a place with computer controlled equipment that can produce different types of objects in various materials and for different purposes. In a FabLab, we can make "*almost anything*"[4]. Based on the "makers" movement[5] and the "*Do It Yourself*" philosophy, the aim of these laboratories is to offer the possibility to anyone to make his own personal and everyday objects or technical systems. It is also a place of co-working and net-working.

There are more than 200 FabLabs all around the world (addresses available from the following site: https://www.fablabs.io). All FabLabs are connected and share their knowledge about digital

[1] http://www.theguardian.com/lifeandstyle/2014/jan/19/3d-printer-bomb-victim-new-arm-prosthetic-limb
[2] http://www.telegraph.co.uk/technology/news/10629531/The-next-step-3D-printing-the-human-body.html
[3] http://www.esa.int/Our_Activities/Technology/Building_a_lunar_base_with_3D_printing
[4] GERSHENFELD, N. A. (2005)
[5] ANDERSON, C. (2012)

manufacturing. This network is also based on the "open source" and "open hardware" philosophy. Apart from some FabLabs built around specific fields like biology, chemistry or specific means of manufacturing, the most common instruments in a FabLab are 3D printers (fig.1), laser cutters, milling machines and some electronic devices. They are often based on a low-cost technology concept and should be replicable in any FabLab. With this typical machinery available locally in any FabLab, someone can produce anywhere an object designed in another country. The FabLab network can be used as a new way to distribute products. FabLabs are also a good instrument during the design process of a product. The different machines of rapid prototyping can be used to test, modify and validate the shape and the function on the basis of an iterative process.

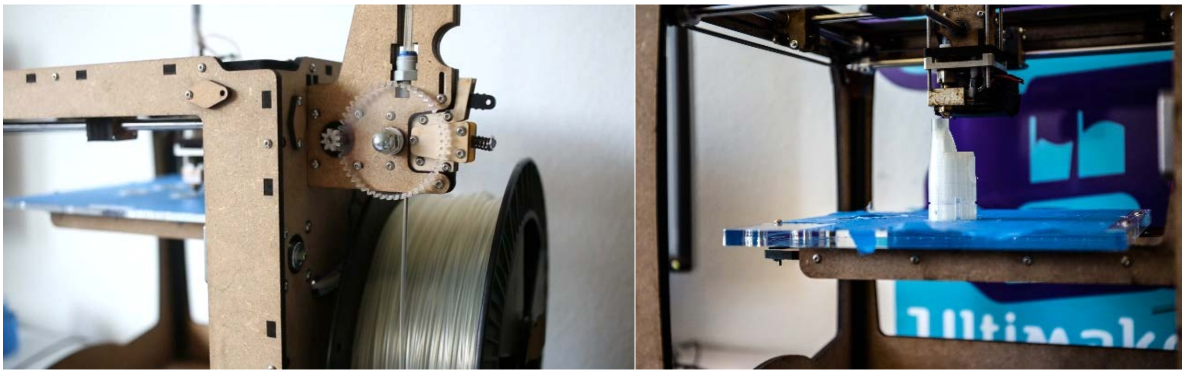

Fig.1: *View of the Ultimaker®: a 3D printer used for the manufacturing of the PLECO. ©FabLab-Neuch*

In addition to being open to the public, FabLabs often organize workshops on specific themes or products: Learning 3D modelling, electronic prototyping, programming or manufacturing of objects of all kinds. The goal is to teach everybody the different ways and possibilities of digital manufacturing.

3D printing in Conservation

Depending on the final use of the printed elements or objects, it is important to choose the proper techniques and materials. As indicated in table 1, each technique of 3D printing uses specific materials according to the application foreseen[6].

Technique	Materials[7]	Specificities
Fused layer Modelling (FLM)	ABS, PC, HD-PE, PLA, PPSF and PCL	Functional pieces, various colour in one piece
Selective Laser Sintering (SLS)	PA, PC, PS, Acrylate, Methacrylate, PVC, PBT, Polyacetal, Elastomer and Metal	Rapid manufacturing possible
Stereo Lithography (STL)	EP, Acrylate, Methacrylate and Vinyl Ether Resin	Good surfaces, various colour in one piece
Layer laminate Manufacturing (LLM)	Paper, PS, PVC, EP, Acrylate, Methacrylate and PE	Plate-like construction
Three dimensional printing (3DP)	PMMA, PVA, PLA and PCL	Rapidity

Tab.1: *Review of the different technologies and related materials of 3D printing.*

The propriety of each printed plastic element needs to be considered such as transparency, cost, accuracy, texture, mechanical property, rapidity of fabrication, toxicity, handling, etc. For cultural heritage applications, the neutrality and the long term chemical stability are undoubtedly essential parameters to consider. As a new born technology, a lot of new polymers are developed with no

[6] MADSACK, D. (2011)
[7] Abbreviations are used for the industrial polymers.

background on their behaviour. For example, the UV resins are not considered stable materials due to the polymerization process occurring during exposure to UV radiation. Accuracy and rapidity of polymerization are prioritised for a commercial use than the long term chemical stability of the final product. We need to be really careful and critical when using such material. Some research needs to be carried out to assess the compatibility of these materials with cultural heritage. Still, there is a lot of potential application using rapid prototyping technology (especially 3D printing and laser cutting) in the cultural heritage field. The laser cutter can be used easily to cut PE foam to prepare quickly and with precision proper conditioning. For exhibition purposes the same techniques can be used on wood, PMMA, PE or other plastics to cut appropriate aesthetical stand to display the objects. It is also possible to consider the laser cutting techniques to replace or refill missing parts of a wood marquetry.

In the same way 3D printing can be used to manufacture filling materials of an incomplete ceramic or to replace broken pieces of a furniture. The advantage of using this technique is that the joining operation can be carried out without any adhering material such as glue[8]. This technology can be very powerful in addition to 3D scanning. That offers the possibility to create a copy of an object without any physical contact and to recreate its original appearance if needed. As an example we can mention the copy of the Persian Horseman made at the Liebegshaus in Frankfurt[9]. Printed in a PMMA materials the replica was painted (fig.2) according to the colours of the original. An object or parts of an object can be produced as positives or negatives that enable to build the product directly or indirectly. For example a mould can be printed from a scanned objet[10]. A copy using loss wax moulding is also possible using the proper printed polymer. This extends considerably the choice of the materials –metals or acrylics resins- used to build the replica but still achievable with low-cost printer. We can also imagine to manufacture models that can be sold as souvenir in a museum shop.

Fig. 2: *View of the Replica of the «Persian Horseman presented at the Libegshaus in Frankfurt ©Alphaform AG*

Finally the rapid prototyping techniques can be used in a different way to develop innovative tools. In the following chapter, we will give an example of such an application.

Saint-Maurice Project

The PLECO

Electrolytic cleaning is a less invasive and safer way to clean silver tarnish in regards to more traditional mechanical and chemical cleaning. The latter abrade the metal surface or might provoke new forms of tarnishing due to inappropriate rinsing processes. Electrolytic cleaning uses more neutral and less concentrated solution to prevent any side effect. Till now, electrolytic cleaning on silver[11] and gilded silver[12] were conducted by immersion. Other applications of electrolytic processes have been

[8] FANTINI, M. & AL. (2008)
[9] VINZENZ BRINKMANN (2011).
[10] WACHOWIAK, M. J. & BASILIKI V.K. (2009)
[11] DEGRIGNY C. ET WITSCHARD. (2006).
[12] DEGRIGNY C., WÉRY M., VESCOLI V. ET BLENGINO M. (1996).

developed such as the stabilisation of active corrosion on lead artefacts[13], the stabilisation of copper chloride [14] and the cleaning of marine iron based artefacts[15].

The electrolytic cleaning of composite artefacts made of inseparable tarnished silver/wood components cannot be carried out by full immersion. The localised cleaning being the only reasonable option, we had to develop a portable, easy to use and safe electrolytic pencil. Some metal conservators - including ourselves - had tested in the past rudimentary versions of an electrolytic pencil with limited success (re-tarnishing of the cleaned spot due to a high concentration of sulphur at the tip of the pencil)[16].The PLECO was designed to solve these problems by providing a constant renewal of the electrolyte and enabling a thorough control of the potential applied. As said before, the PLECO (fig.3 & 4) has been conceived using 3D printing elements (**1.**tip, **3.**piston head & **5.**cover) and assembled laser cutted pieces (**2.**envelop & **4.**piston):

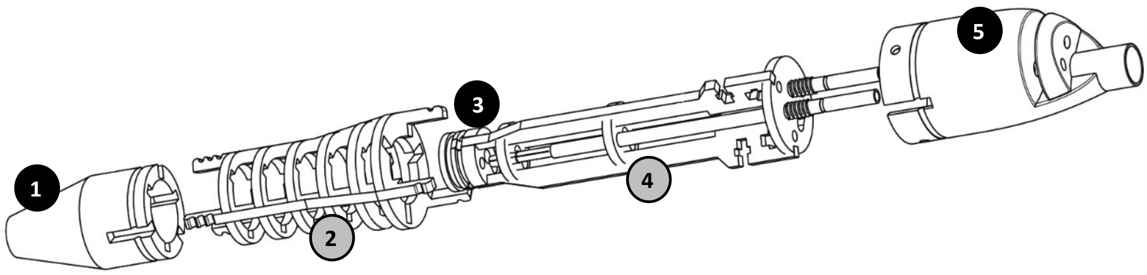

Fig.3*: Exploded view of the PLECO ©EDANA*

The PLECO (fig.4) has been designed to be built by conservators through a FabLab, the rest of the elements being purchased in specialised stores or manufactured by specific workshops (brass electrode holders). All the schematic drawings and manuals are available on the FabLab-Neuch' webpage (http://fablab-neuch.ch/projet/pleco)[17]. In the near future the PLECO will be made available as mounted but conservators will have as well the possibility to be trained through workshops to build their own PLECO. As an open source tool, modifications provided by end-users on the CAD files according to their needs will be possible as well as the transfer of this knowledge to the community of end-users using the PLECO webpage.

Fig. 4*: View of the PLECO ©HE-Arc CR*

The PLECO, how it works

As said before, the PLECO is used for the localised electrolytic cleaning of silver/gilded silver tarnishing. It is equipped with a 3 electrodes cell – a platinum counter electrode, a vitreous carbon rod used as a reference electrode (both situated inside the PLECO (fig.5) and the object to clean being the working

[13] DEGRIGNY, C. et LE GALL, R. (1999).
[14] DE GROOT, I. et DEGRIGNY, C. (2004).
[15] DEGRIGNY, C. (2005).
[16] WOLFE J., BOUCHARD M. et DEGRIGNY C. (2010).
[17] The website is currently being filled with manuals and conception files. An English version should be available in Spring 2014

electrode. The PLECO and the object are connected to a stabilised power supply, the object being plugged as a cathode and the platinum wire as the anode. A voltmeter is added to control the potential between the reference electrode and the object. Therefore the conservator can follow and control precisely the parameters of the electrolytic reduction.

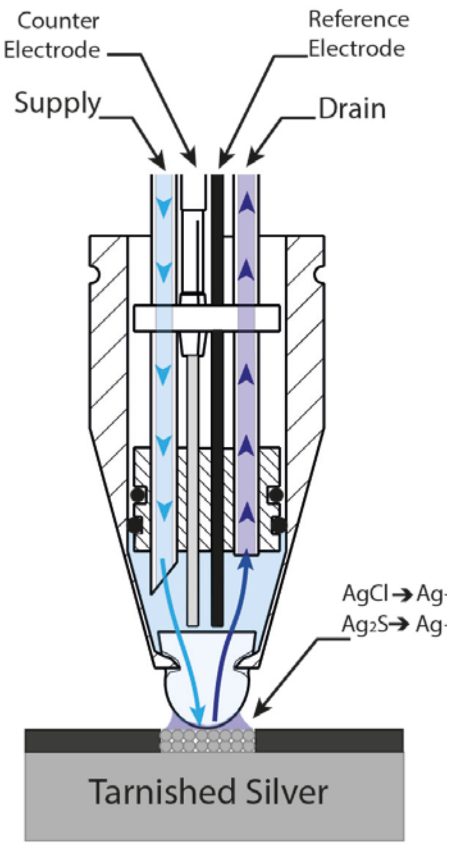

Fig. 5: *Sectional view of the PLECO electrolytic cells. ©HE-Arc CR*

A pad made in a microporous sponge (PVFM AION®) is mounted at the extremity of the pencil. When wet, it ensures a proper electrical contact with the object without any outpouring of the electrolyte. The renewal of the electrolyte is made possible with two membrane pumps. They respectively supply the electrolytic cell with the fresh electrolyte from a reservoir and drain back the sulphur/sulphide and chlorinated polluted electrolyte after the cleaning process. No re-tarnishing is observed with this new developed system (fig.6).

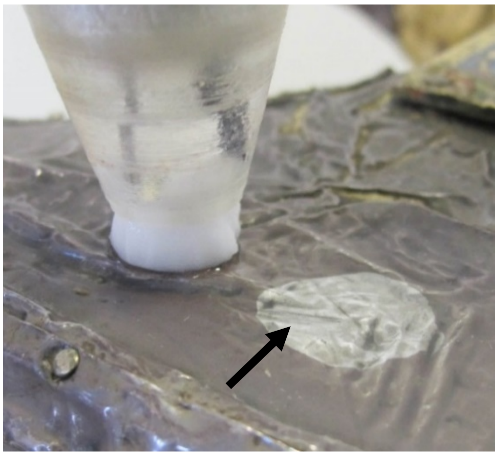

Fig. 6: *Detailed view of a cleaned spot (black arrow) and reduction in progress with the PLECO. ©Abbaye Saint-Maurice*

Conclusion

Through the example of the fabrication of the PLECO we see that the "FabLab technology" is not limited to designers, engineers and artists. The conservation field has many potential use of 3D printing, laser cutting, etc. In addition to the PLECO itself we plan to manufacture the pumping system using similar tools. This should decrease tremendously the cost of the PLECO. Furthermore more research has to be carried out to investigate the compatibility of printed polymers with cultural artefacts. The PLECO project shows that such a tool can be disseminated in a professional community and we expect a self-appropriation of the tool by end-users to optimise it. As an example, an HE-Arc CR master student has chosen to apply the PLECO for the stabilisation of active corrosion on lead artefacts.

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