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Exploring the Creative Possibilities of Argentium™ Sterling Silver

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1. Introduction

This paper documents the aims, conduct, and outcomes of research undertaken by Dr Kristina Niedderer as Artist in Residence in the Department of Applied Arts, Middlesex University from February to July 2005. The research was conducted in collaboration with Peter Johns and Clare Harrison of the Argentium Silver Co. Ltd. Research Project and it was supported by a grant of the Arts Council England and by internal research funds.

The project set out to investigate the creative possibilities of Argentium™ Sterling Silver, which was invented by Peter Johns at Middlesex University. Argentium™ Sterling Silver has been recognised as a significant development in the history of silver through the grant of patents and through winning a prestigious AJM Innovation~~s~~ Award, 2004. It has been recognised for a number of advantages in comparison to Standard Sterling Silver, most significantly for being firescale-free and highly tarnish-resistant.

The **Aims** of the research:

On a technical level, an investigation into the creative possibilities of Argentium™ Sterling Silver has been conducted in order to complement scientific research and testing. The aim of this exploration was an assessment of the material's qualities and 'behaviour' within practical application and identification of strengths and weaknesses in the use of the material in order to make recommendations for its use in creative practice of relevance both to makers and industry. Of particular interest was exploration of the use of new technologies such as laser welding and laser bending, which can be applied due to the increased thermal resistance of Argentium™ Silver.

On an artistic level, these new possibilities were explored with regard to understanding silver in a new way and to expressing this understanding through developing a new formal language.

On a conceptual level, the aim was to use the designs as a means for exploring mindful interaction through the use of artefacts in social contexts (Niedderer 2004). Artefacts, especially those used in the context of social gatherings, fulfil a social role that goes beyond physical and aesthetic satisfaction. Playing with the notion of function to achieve engagement, the aim was to encourage the users to explore and reflect on their social interactions within which the artefacts are used.

Accordingly, the **Objectives** of the project were:

a) To create 2 pieces of work made in Argentium™ Silver.
b) To use (at least) 6 different techniques in the process (e.g. spinning, welding, soldering, polishing), some of which are new (e.g. traditional sterling silver is difficult to weld).
c) To assess possible differences in working with the material as compared to traditional sterling silver and to document them.
d) To use the proposed work to explore the theme of the expressive potential of function with regard to creating mindful interaction.

Concerning the **project development**, in a preliminary phase of co-operation with the Argentium™ Research Team (February – April 2005) a small number of jewellery works was created by the researcher to get familiar with the new material, and to identify which techniques may be most important to be tested in/through creative practice in the subsequent main part of the research project. Subsequently, in the main phase of the research (May – July 2005), which is reported on here, two tableware designs were developed and made. It was thought that the larger scale and complexity of tableware would be useful for the testing because it would be more demanding (than jewellery), and therefore more revealing with regard to the properties and opportunities of the material. In line with the objectives, during the course of the research two designs were created, and the following techniques were used/explored, which were selected according to expectations of (differences in) performance of the material as well as their suitability for the designs.

Main Techniques/Technologies	**Additional Techniques**
• Work hardening through rolling & precipitation hardening • Laser welding • Laser bending • Spinning • Soldering • Surface finishing	• Annealing • CNC-cutting • sawing, filing, scoring • sinking/die-forming, bending • drawing (wire)

The paper begins with a description of the material Argentium™ Sterling Silver and its characteristics. This description will be followed by a summary of the two projects/designs undertaken, including a description of technical, artistic, and conceptual considerations. The paper then provides a detailed documentation of the techniques/technologies used and tested, including a comparison and assessment as to whether any differences have been identified in working with Argentium™ Sterling Silver as compared to Standard Sterling Silver, and what these are. The paper concludes with a summary and brief evaluation of the project.

2. Argentium™ Sterling Silver: The Material and its Research

Standard Sterling Silver is the silver alloy that is traditionally used for jewellery and silverware. It contains 92.5% fine silver and 7.5% Copper. The copper content increases the hardness of the silver and so makes it more durable. Introducing copper into the silver has, however, a major disadvantage. Because silver allows oxygen to penetrate through the surface into its structure when heated, the copper that is contained in the alloy will oxidise in the upper layers of the silver, and the copper oxide will appear as dark stains in and underneath the metal surface.

Argentium™ Sterling Silver is a patented and trademarked alloy, and like traditional Sterling Silver has a silver content of at least 92.5%. The difference to traditional Sterling Silver is that part of the copper content is replaced by the element Germanium, which is a metalloid (half-metal). The addition of Germanium changes some of the characteristics of the new silver alloy. Most importantly, when Argentium™ Sterling Silver is heated, the Germanium oxidises before the copper can oxidise. The Germanium oxide prevents oxygen penetrating into the metal surface and thus prevents the oxidising of copper and the building of firescale. It also slows down the reaction of silver with sulphur (which is e.g. contained in the air) and so enhances the tarnish-resistance of Argentium™ Sterling Silver (Eid 2005).

Argentium™ Sterling Silver has been recognised for these as well as other benefits – a summary of advantages in comparison to Standard Sterling Silver is listed in *A quick guide for using Argentium™ Sterling Silver* (Argentium™ Silver Co. Ltd. 2005)

- Firescale-free alloy.
- Highly tarnish-resistant.
- Lower heat and electrical conductivity, enabling the alloy to be resistance, plasma and laser welded.
- Annealed hardness is equal to standard sterling silver. Further hardening can be achieved by simple heat treatment (even after soldering).
- Increased ductility, to assist forming processes including spinning and stamping.
- Environmental advantages of a firescale-free alloy – cyanide and other hazardous chemicals used for stripping or plating over firescale, are eliminated.
- Production/finishing time is reduced.

In relation to the celebrated qualities of Argentium™ Sterling Silver, one needs to add a few words about the research of which this invention is the result. The research into Argentium™ Sterling Silver, which has been carried out by Peter Johns and Clare Harrison at Middlesex University, has taken about fifteen years of persistence and hard work to develop an alloy which would succeed in the market place through combining the best possible qualities. Throughout the research, a large number of silver alloys have been produced and each has been tested with scientific methods towards its various and desired characteristics.

Alongside the scientific research, a number of practitioners have used and tested Argentium™ Sterling Silver within and through their practice. This voluntary research through practitioners has proven useful, because some characteristics would be revealed much more clearly in practice, where the material is used in complex processes (Niedderer, 2005). The alloy in its most recent state has also inspired some practitioners who have used the alloy to report on their experiences (Eid 2005; Trevor 2005). While these accounts contain interesting and valuable information, they are often emotional accounts, which are not as systematic and rigorous (and therefore not as sound) as they would need to be to provide reliable advice and feedback both for practitioners and for the Argentium™ Research Team. For this reason, the research that is documented in this paper has been undertaken.

3. Exploring the creative possibilities of Argentium™ Sterling Silver: The Designs

The two designs have been developed according to a number of considerations. On a technical level, the designs were intended to explore both traditional techniques (Design 1) and new technologies (Design 2). The choice of techniques/technologies was sought to be as widespread as possible, however the choice remained subject to the development of the designs' formal and conceptual intentions, which are explained below.

Design 1: "Imprints" (Illustration 1), was developed according to the artist's conceptual aim of exploring design as a means for creating mindful interaction through the use of artefacts in social contexts. The design plays on the understanding that people are formed by their interactions with other people. "Imprints" is designed as a visual metaphor of this form-giving process that occurs within social interaction, giving each of the otherwise uniform cups its own character. The visual aspect is enhanced through inviting the users' engagement to match the positive and negative forms, puzzle-like, thus aiming to draw the users' attention to their interactions and to reflect on them. The formal language of *"Imprints"* was mainly determined by the conceptual considerations. In the making, mainly traditional techniques were used and explored (spinning, annealing, sawing, filing, scoring, sinking, soldering, surface finishing). Additionally, laser-welding was used on some parts in support of the traditional ways of working. The technical details are discussed in Section 4.

Illustration 1: "Imprints (Social Cups 2)"
Date: July 2005. *Material:* Argentium™ Sterling Silver.
Dimensions: 6 Cups: Ø73mm x 80mm.

Design 2: "Duo" (Illustrations 2 + 3). In contrast to *Design 1*, for *Design 2* mainly new technologies were explored (CNC-cutting, laser welding, laser bending). The aim was to investigate:

- whether the new material is suited (better/less) to the use of these new technologies,
- what influence these new technologies might have on what can be done with silver, and
- their influence on the development of a formal language that would be appropriate to their use as well as to a contemporary understanding of silver.

In accordance with this aim, a set of two small cups was developed using laser-welding technology for its fabrication, which allows the use of thin hard-rolled material for the cups. Similar to paper-cut-outs, flanges provide space for the welding seams and, at the same time, their extension provides the material for small handles. The thin, hard material and straight shapes give the cups a technical feel, while the welding seams have the character of sewing or stitching. With the intertwining handles, the small cups convey a somewhat comic-strip-like character.

Illustrations 2: "Duo"
Kristina Niedderer.
Date: July 2005. *Material:* Argentium™ Sterling Silver. *Dimensions:* Ø43mm x 60mm.

Illustrations 3: "Duo"
Kristina Niedderer.
Date: July 2005. *Material:* Argentium™ Sterling Silver. *Dimensions:* Ø43mm x 60mm.

4. Exploring the creative possibilities of Argentium™ Sterling Silver: Technical Descriptions and Tables

This section documents the technical investigation carried out within the research. It describes the techniques used in the two designs, including their significance and how they were explored/tested. The section explains the technical results and makes a number of recommendations about the working with Argentium™ Sterling Silver.

4.1 Design 1: "Imprints"

Design 1 consists of 6 cups (Ø=73mm (top), Ø=36mm (base), h=80mm). They are of a slightly rounded conical shape. Each cup features one full-bodied hollow geometric shape, and one negative-section of a geometric shape (segment), which in turn corresponds to a full-bodied hollow geometric shape in one of the other cups. Thus the cups can be matched according to their full-bodied shapes/segments.

In the making, mainly traditional techniques were used/explored. These were:

- spinning (testing ductility)
- annealing (testing sensitivity to heat treatment)
- sawing, filing, scoring (testing cutting-qualities)
- sinking/die-forming (testing ductility)
- soldering (testing soldering flow)
- surface finishing (sanding, polishing; testing surface qualities)
- drawing wire (ductility)

Additionally, laser-welding was used on some parts in support of the traditional ways of working.

The use of these techniques covers many of the basic processes (cutting, joining, forming, finishing) used in (gold- and) silversmithing. A description of the making process is given below, and a detailed technical description of the testing of all processes, which are underlined in the text, can be found in the table underneath the text.

The Making Process

The 6 cups were spun on a brass chuck by a professional spinner located in Greater London. Spinning was used instead of hand-raising as a matter of efficiency. The cups were spun from Argentium™ Sterling Silver discs Ø=130mm, t=1.0mm. The cups were subsequently surface-finished (1). They were sanded (inside & outside) to eliminate any traces from the spinning, and the rim was shaped through filing, rounding it on the inside of the cups. The cups were polished on the motor to finish their surface. They were then annealed to take out any stresses before the geometric shapes could be fitted into the cups.

Next, the full-bodied geometric shapes and their matching segments were made. Argentium™ Sterling Silver (t=0.8mm) was used for these shapes. The shapes chosen were a cube, a double pyramid, a sphere, a lens-shape, a 6-facetted cone, and a polygon. The projected plans of these shapes were drawn onto the sheet metal and sawn out. The rounded shapes were sunk/die-formed out of two halves and then soldered together. The angular shapes were filed, scored, folded, soldered, cleaned and polished. Before soldering, the full-bodied shapes were pierced with a drill (Ø0.8mm) to allow the trapped air to expand when heated.

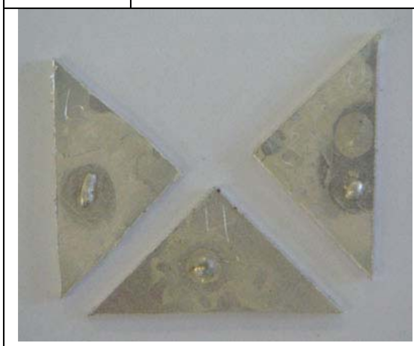
The third step was to fit and solder the geometric forms and segments into the cups. Special care had to be taken that matching forms and segments were fitted in exactly the right positions (height, angle, etc). In order to make the soldering easier, the forms were temporarily fixed into the cups with tape and then laser-spot-welded in three places to fix them in exactly the right position in the cups. Where necessary, 0.3mm Argentium™ wire was used to provide material for the welding. This use of the new technology has proven very useful, easing the otherwise delicate process of soldering. After the soldering, the holes in the geometric shapes was welded closed using Argentium™ wire in the appropriate thickness, and the cups were cleaned up and surface-finished (2) with a fine brass brush.

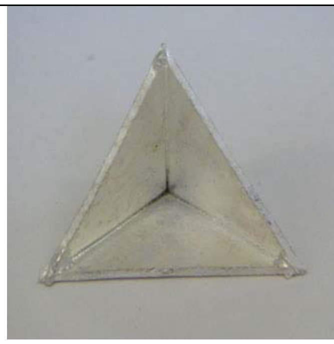
Detailed Descriptions of the Technical Investigation and Testing

1) Materials used	Argentium™ Sterling Silver: sheet 1.0 and 0.8 mm; wire Ø 1.0 mm. Argentium™ Prototype Solders: no.6 (hard), no.1 (easy), no.3 (hard), no.4 (easy). Soldering fluid: Degussa h Flux paste; Thessco F Flux powder.
2) Spinning	The 6 cups were spun by a professional spinner first over a wooden and finally over a brass chuck from discs Ø=130mm, t=1.0mm. The spinner had spun Argentium™ Sterling Silver at an earlier stage of its development, about five years ago. In comparison with this previous

	experience, the spinner reported a perceived improvement in spinning the material. The following observations were made: - the annealing of Argentium™ Silver (cf. 4. annealing) is more sensitive than of standard Sterling Silver, because it shows a paler colour, sags more easily when overheated, and is brittle when at annealing temperature. The piece therefore needs to be left to cool down for a few seconds after annealing and before quenching. - After annealing, the material is softer and can be spun for longer without annealing. It can therefore be stretched further, and can be made harder than Sterling Silver. - Argentium™ Silver gets somewhat hotter during spinning (because of the reduced heat conductivity). - After spinning, the rim of the cups shows a slight wave, which is of smaller frequency than is found with Sterling Silver.
Illustrations 4 + 5: Cups as received after spinning	 
3) Surface finishing (1): **sanding, polishing (testing surface qualities)**	Following the spinning, the cups were sanded (inside/outside: grain 400, 600, 800-polishing paper) to eliminate any traces from spinning, and the rim was filed, rounding it on the inside of the cups. The cups were polished (inside) on the motor to finish their surface. Polishing components used: emery compound (brown) on a cup-brush; Unipol polishing compound (light blue) on a wool cup-brush. Afterwards, the cups were cleaned with ultrasound (using a general washing-up liquid). *Observations:* No differences to sanding/polishing standard sterling silver can be reported.
Illustrations 6 + 7: Cups after polishing (inside polished, outside emery-paper and brass-brushed finish)	 
4) Annealing	The cups were then annealed to take out any stresses before the geometric shapes could be fitted into the cups. *General advice:* Argentium™ Silver shows a paler colour than Sterling Silver when annealing. Annealing in a darkened area is therefore

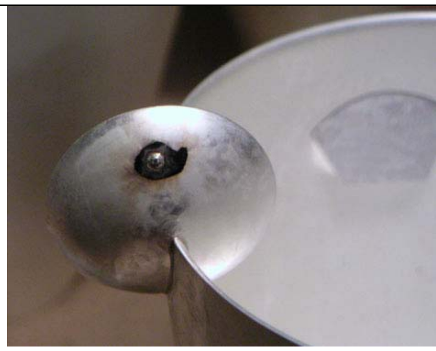
(testing sensitivity to heat treatment)	recommended. Own experience seems to suggest that with practice one can learn to distinguish the different colours in a similar way as with Sterling Silver, even though the colours appear more subtly. This colour difference, together with Argentium™ Silver not dissipating heat so quickly as Standard Sterling, means that care must be taken not to manipulate the alloy at red-hot temperatures, as this can cause cracking. An annealed piece needs to be left cool down for a few seconds, before quenching. The alloy also sags more easily when overheated. In an annealed state, the alloy is slightly softer than standard sterling silver, but can be easily precipitation hardened to 120 HV/DPH, at temperatures achieved in a domestic oven. *Observations*: slight dis-colourations or blackening may appear after annealing, e.g. caused by talo which is used as lubricant. Any surface staining is not fire-scale and therefore can be easily removed through pickling.
5) sawing, filing, scoring (testing cutting-qualities)	Production of full-bodied angular, geometric shapes and their matching segments using sawing, filing, and scoring. *Observations*: No differences to working with Sterling Silver can be reported, apart from the fact that the scoring seams do not break as easily as with Sterling Silver when they are bent because of the greater ductility of the material.
6) sinking/ die-forming (testing ductility)	Production of full-bodied, rounded geometric shapes and their matching segments using sinking/die-forming. *Observations*: No differences to working with Standard Sterling Silver were found, except for a lesser need to anneal because of the greater ductility of the material.
7) soldering (testing soldering flow)	All geometric shapes were soldered with Argentium™ no.3 solder. The shapes were soldered into the cups with no.4 solder. This was determined after some simple comparative tests of the solders available to the researcher. Argentium™ Solders tested: hard (no.6), easy (no.1), hard (no.3), easy (no.4). (The composition of the solders cannot currently be made public, because of patenting rights). *Test 1:* 4 pallions of same size (1 of each type of solder) were placed on a piece of Argentium™ Silver and evenly heated until the most easy-flowing solder had flown (Illustration 8). This test served to verify the relative flow-temperature. *Test 2:* one angular piece was soldered with the two different hard solders (no.6, Illustration 9; no.3, Illustration 10) to compare their flow-qualities. The test showed that solder no.3 had significantly better flow-qualities than solder no.6. and was therefore chosen for the soldering of the geometric shapes. *Test 3:* one angular piece was soldered onto a flat surface using the two different easy solders (no.1 and no.4; Illustration 11). Solder no.4 seemed to flow more easily (smoother surface), although there was no great difference. Solder no.4 was chosen for soldering the geometric shapes into the cups. *Test 4* shows the flow-quality of the two chosen solders (no.3 + no.4). In Illustration 12 can be seen that the easy solder produces a smoother soldering seam than the hard solder.





<table>
<tr><td>Illustration 8: Test 1 – four solders</td><td>Illustration 9: Test 2 (solder no.6)</td><td>Illustration 10: Test 2 (solder no.3)</td></tr>
<tr><td>Illustration 11(left):
Test 3: solder no.4 (image left) + solder no.1 (image right)

Illustration 12 (right): Test 4: solder no.3 (image left) + solder no.4 (image right)</td><td></td><td></td></tr>
<tr><td>7) soldering (continued)</td><td colspan="2">Observations:
1) The soldering of the geometric shapes with Argentium™ no.3 solder went smoothly, although the perception was that soldering was not as easy as with standard hard solder. This may, however, be partly due to the complex shapes, where deflection of heat etc. might have occurred.
2) After cleaning and polishing the geometric shapes, they were fitted and fixed with spot-welds into the cups (cf. 9. laser-welding) so that the cups could be conveniently positioned for the soldering for which no.4 solder (easy) was used. The solder performed exceptionally well during these rather delicate and extended solderings and could be made to flow up to three times. Also, the soldering seams were smooth and without air-bubbles etc.
3) The use of flux: Degussa h or Thessco F fluxes were used for the soldering.
After removal of the Fluxes through safety pickle, both fluids were found to leave slight discolouration on the surface of the silver (cf. Illustr. 11 + 12). Explanation: the Germanium contained in the silver needs oxygen to develop its protective function. The soldering liquids create a reductive atmosphere which prevents this. However, any copper stains are on the surface only and disappear with pickling.</td></tr>
<tr><td>8) drawing wire (ductility)</td><td colspan="2">Wire (Ø0.8mm) was drawn from a piece of raw ingot to close the holes in the hollow geometric shapes. The rolling and drawing of the wire (from ✐ 6x6mm to Ø 0.8mm) was extremely easy with no splintering of the wire.</td></tr>
<tr><td>9) Laser-welding</td><td colspan="2">Laser-welding was used 1) for pinning the geometric shapes into the cups to ease the soldering process and 2) for closing the holes in the geometric shapes. For a general description of laser welding cf. §4.2 Design 2.
1) In preparation of the soldering, the shapes were temporarily positioned with tape and then welded in three places to fix them in exactly the right position in the cups. Where necessary, 0.3mm Argentium™ Silver wire was used as fill-material (Illustration 13). This use of the new technology has proven very useful to ease the otherwise delicate process of soldering.
2) The holes in the geometric shapes were closed with laser welding. A tightly fitting wire was inserted into each hole and the laser used to melt the wire into the material around the seam (Illustration 14). The availability of the laser-welding technology was of great benefit. It allowed the holes to be closed after the soldering and thus permitted the use of hollow forms on the cups.</td></tr>
</table>

Illustration 13(left): spot-welding can be seen at the top of the half-sphere Illustration 14(right): hollow lens-shape closed with laser-welding		
10) Surface finishing (2) (sanding, polishing)	After the final soldering and welding, the cups were cleaned up. Excess material was filed away and the surface finely sanded (400, 600). The cups were polished on the inside with a wool-cup-brush and by hand.	

4.2 *Design 2: "Duo"*

Design 2 consists of 2 small cups of conical shape (Ø=43mm (top), Ø=32mm (base), h=60mm; *cf. Illustr. 3 + 4).* They are made of thin hard-rolled sheet material (t=0.25mm) using laser-welding technology for their fabrication. Flanges provide space for the welding seams and, at the same time, their extension provides the material for the handles. Each cup has a differently shaped handle - one round with a hole and one long, slim and bent – so that one can be made to grip the other.

Design 2 used and explored new trendsetting technologies, thereby utilising the ductility and flexibility of metal rather than CAD/CAM technologies that are bound to casting. The following technologies were explored:

- CNC cutting
- laser-welding
- laser-bending

A detailed description of the making process is given below, and a description of the listed/underlined processes can be found in the technical table underneath.

The Making Process

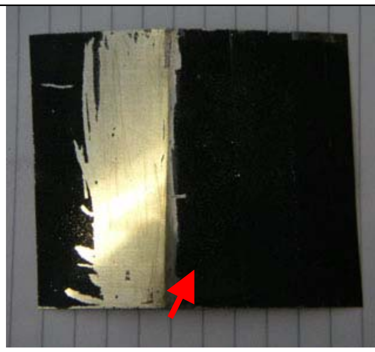
For the two small cups, projected plans were drawn on the <u>thin, hard-rolled sheet metal</u> (t=0.25mm) and cut out. The current set of cups was cut out by hand with snippers, but <u>CNC-cutting</u> has been tested and offers an excellent option for larger production runs. The edges of the cut-outs were filed and steel-polished, and the surfaces finely sanded and hand-polished. The flanges of the cut-outs were then bent in a right angle to one side, using a vice with two pieces of wood for protection. For the base of the cups, two discs (Ø=32mm) were domed and a ring (h=3mm, t=0.6) with the same cone as the cups soldered onto each (for soldering cf. *Design 1*). The bases were cleaned and polished and, together with the cut-outs, prepared for <u>laser-welding</u>. The bodies of the cups were first welded along the flanges and handles, then the base was welded in. Finally, the surfaces were polished (inside) and finely brushed with a brass-brush (outside) and the handle of the second cup was bent into position. Laser-bending has been considered and tested for enhancing some of the features of the cups, however more research is required before the technology can be successfully applied in creative practice.

Detailed Descriptions of the Technical Investigation and Testing

1) Materials used	Argentium™ Sterling Silver: sheet t=0.25mm (hard rolled) & t=0.6 mm; wire 0.5mm and 1.0mm drawn from ingot. Argentium™ Prototype Solder: no.3 (hard), no.4 (easy). Soldering fluid: Degussa h.
2) Thin hard-rolled sheet metal	Before the material for the cups was ordered, tests were conducted to compare the work-hardening of standard Sterling Silver and of Argentium™ Sterling Silver. The comparison was made against the technical values (Appendix: *Table 1*). The results of the testing (technical details: Appendix: *Table 2*) conveyed the perception that annealed Argentium™ Sterling Silver was slightly softer than annealed standard Sterling Silver. Hard rolled Argentium™ Sterling Silver and standard Sterling Silver seemed to display similar hardness, however, Argentium™ Sterling Silver appeared more springy, i.e. elastic and flexible. Accordingly, hard-rolled Argentium™ Sterling Silver (t=0.25mm) was ordered.
3) CNC-Cutting	Although the current set of cups was cut out by hand with snippers, CNC-cutting was tested in the preliminary phase of the research for two jewellery designs (a set of bangles and a neckpiece, Illustrations 15, 16). Each design consisted of a repetition of identical shapes that were cut with CNC. The cutting worked very well with the 0.25mm thin, hard rolled material and can be recommended, especially for larger production runs. The jewellery pieces demonstrate how the ability to CNC cut and laser weld thin (0.25mm thickness), hard Argentium™ Silver sheet, opens new avenues for jewellery design and production, because the working process facilitates the creation of larger, complex, and durable, yet lightweight designs that benefit from technical and material efficiency.
Illustration 15(left): Laser welded Argentium™ Silver neckpiece Illustration 16 (right): Argentium™ Silver bracelets. Kristina Niedderer, 2005.	 

4) Laser-welding Illustration 17: Laser Welder at Goldsmiths' Hall	*General:* Laser welding of Argentium™ Sterling Silver had been reported by industry to show excellent results in chain making. A full penetration of the welding seam was achieved with Argentium™ Sterling Silver, which was reported not possible with Standard Sterling Silver (Argentium™ Silver Co. Ltd. 2005b). This raised the aim to try laser welding on larger scale pieces where soldering would provide problems. Therefore, in this research, laser welding has been used e.g. for using spot-welding to preliminary fix two pieces together (*design 1)*, for closing holes needed for soldering (*design 1*), and for joining two sheets of metal either on their edges or flat on flat (*design 2*). *Machine:* A yag-laser-welder (Rofin System) has been used for all tests/work undertaken. Thereby all tests were conducted using the laser-welder of the Jewellery Innovation Centre, BIAD, Birmingham; the work on the actual pieces was undertaken using the laser welder of the Goldsmiths' Company, London (Illustration 17).
 	*Process:* The laser used is a spot-welder. The laser-beam is fixed in space and the work has to be presented to the laser. The laser has to be adjusted according to the material, its thickness and the nature of the weld. The laser has four parameters that can be adjusted: - Voltage: responsible for the overall strength of the beam, - Ms (milliseconds): controls the penetration of energy into the metal, - Ø (diameter): regulates the diameter of the laser beam and thus the energy/mm2 - Hz (frequency): the frequency with which the laser pulse is released

	The overall energy that results from the combination of the four parameters is expressed in kilo joule (kj). One peculiarity of working with silver is that the area that is to be welded has to be coloured with a pen, because otherwise the laser is reflected by the highly reflective surface of the silver. *1) Comparative testing of Sterling Silver and Argentium™ Silver:* The characteristics of welding together two flat sheets of either Sterling Silver or Argentium™ Silver have been compared. For settings cf. Appendix: *Table 3* (entries 1-3). The result has shown that less than half the energy is needed for welding Argentium™ Silver, than is required for standard Sterling Silver. *2) Welding conducted on Design 2:* For welding the body of the cups, flat sheets were welded together. A double seam was created. Each seam was welded once and then smoothed over with a larger diameter beam and lower Ms setting (Appendix: *Table 3,* entries 4-5). The base was welded with a single seam. Slightly higher power was needed here because of the thicker material of the base. Additionally, the edges of the base and the body were welded together, which required slightly less energy than welding flat sheets. Where the base meets the joint in the body of the cup, a small gap had to be closed using wire (0.5 + 1.0mm as appropriate) by melting excess material onto the main material and smoothing it over with the laser afterwards. *Specific comment on the use of laser-welding:* This project has shown that the use of the spot welder requires a substantial amount of practice to achieve acceptable results (e.g. evenness and straightness of the seem). Computer-guided systems could easily overcome this, but are currently only available to larger manufacturers because of cost. For silverware, the exploration of seam welders would be beneficial.
	General comment on laser-welding: The use of laser-welding offers opportunities previously unavailable, by allowing parts of a piece to be joined without having to heat the piece. This gives e.g. the opportunity to use/join thin, hard, and very elastic material, as has been done in the case of the two cups, while preserving the elastic quality of the material. This reduces weight and also allows for relatively quick working, which might open new dimensions for silver production. It also offers new avenues for design because of the characteristics of the technology, e.g. of requiring flanges or seams, which can create a different feel of the design, e.g. cool/technical and/or comic/humorous.
5) Laser-Bending	Laser-bending works by inducing local stresses in the metal through local heat transfer through the laser, which causes the metal to bend (Illustrations 18, 19). The intention was to use laser-bending to round off the edge at the top of the cup to give it a lip that would be pleasant for drinking. It was also hoped that positive and negative geometric shapes (similar to those in *Design 1*) could be achieved by this technology (Illustr. 20). In the end, the technique of laser-bending was explored but not used, because more research would have been needed achieve satisfactory application. The demonstration/test on Argentium™ Sterling Silver, however, has shown promising results (Illustr. 21), which may be exploited through further

	research.
	
Illustration 18: Laser-bending machine at Brunel University.	Illustration 19: Sample of laser-bending in Standard Sterling Silver by Dr S. Silve, Brunel University.
	
Illustration 20: model for small cups with positive and negative geometric shapes.	Illustration 21: sample of laser bending of Argentium™ Sterling Silver (t=0.25mm). The bend (red arrow) is particularly crisp, which promises good results in future research/applications.

5. Summary of the Research & Research Findings & Conclusion

This research set out to complement technological research into Argentium™ Sterling Silver by exploring its qualities within creative practice through the design of two silverware pieces.

The first project *(design 1)*, using mainly traditional techniques, has revealed

- Excellent working qualities of Argentium™ Sterling Silver, e.g. in terms of ductility, no firescale or other stains were found after spinning.
- Some differences in working with the material, e.g. in terms of annealing.

The second project *(design 2)*, exploring new technologies, has shown that:

- Argentium™ Sterling Silver is well-suited to the use of laser-welding (e.g. more economic) and laser-bending (e.g. clean + crisp bends);
- the use of laser-welding and laser-bending offers new technical possibilities, such as the use of thin material for strong but lightweight constructions suitable for production;
- the utilisation of laser-welding (and possibly laser-bending) can offer new avenues for designing silver due to the characteristics and possibilities of the technology. For example, laser-welding requires/produces flanges or seams, which can create a different feel of the design (e.g. cool/technical, comic/humorous); and it offers the creation of strong and complex but lightweight forms. It thus offers the development of new formal language which may help (re)forming contemporary views of the material silver;
- more research is needed into the application of these technologies in the creative process.

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Appendix:

***Table 1**: Hardness of Sterling Silver and Argentium™ Sterling Silver*

Table1: Hardness (according to Stern-Leach 2005)	**Standard Sterling Silver**	*Argentium™ Sterling Silver*
Annealed	70	65
Work hardened	145	155

***Table 2**: Tests on Work Hardening of Sterling Silver and Argentium™ Sterling Silver*

Table2: Tests on Work Hardening (some tests including precipitation hardening)				
	Starting Material	Outcome		
		Rolling	*Bending 360°*	*Tempering*
1	Standard Sterling Silver, 1.0mm	1.0 ⇒ 0.25 hard, dull	breaks	---
2	Argentium™ Sterling Silver, 1.0mm	1.0 (prec.-hard.) ⇒ 0.25 very hard, dull	breaks	---
3	Argentium™ Sterling Silver, 1.0mm	1.0 ⇒ 0.25 hard, springy	Orange skin, near to breaking	---
4	Argentium™ Sterling Silver, 0.6mm	0.6 ⇒ 0.25 hard, springy	Bends ok	With tempering: springy but more dull + resistant to bending
5	Argentium™ Sterling Silver, 0.6mm	Annealed 0.6 ⇒ 0.25, medium hard	Bend: creates orange skin	Same as above
6	Argentium™ Sterling Silver, 0.6mm	0.6 ⇒ 0.25 annealed, soft	Bends good	With tempering: no detectable improvement

Table 3: Tests and Settings for Laser Welding of Sterling Silver and Argentium™ Sterling Silver

Table3: Tests and Settings for Laser Welding (1-3: BIAD; 4-5 Goldsmiths' Hall)							
	Starting Material	Settings					Comments
		KJ	*Volt*	*Ms*	*Ø*	*Hz*	
1	Argentium™ Sterling Silver, 0.25mm (test)	1014	260	1.8	4	3	Best setting for welding the edge of one sheet onto another flat sheet (Illustration 22)
2	Standard Sterling Silver, 0.25mm (test)	1014	260	1.8	4	3	Hardly any penetration on a flat sheet on same settings (Illustration 23)
3	Standard Sterling Silver, 0.25mm (test)	2308	330	1.8	3	2	Best setting for welding the edge of one sheet onto another flat sheet for Standard Sterling. Note that more than twice the energy is needed!
4	Argentium™ Sterling Silver, 0.25/0.25mm	?	270	2.1	2-3	3	Best setting for welding two sheets flat together (weld 1)
5	Argentium™ Sterling Silver, 1.25/0.25mm	?	270	2.0	7	3	Best setting for welding two sheets flat together (weld 2: bigger Ø for smoothing the seam)

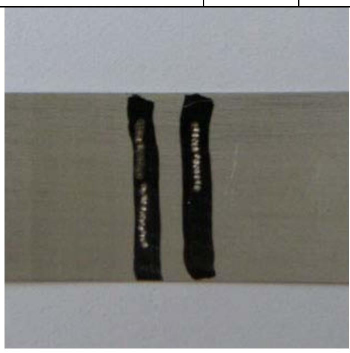

Illustration 22: Hardly any penetration on Standard Sterling Silver sheet

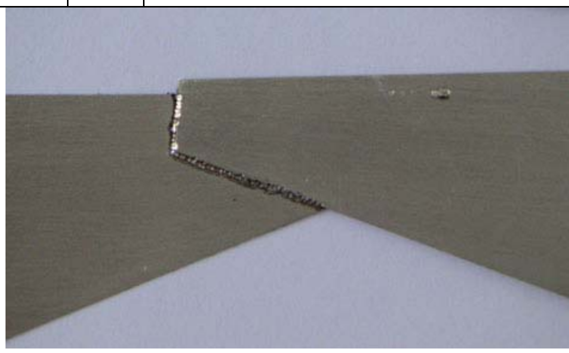

Illustration 23: welding the edge of one Argentium™ Sterling Silver sheet onto another flat sheet

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Additional sources:

Information on the history and characteristics of Argentium™ Sterling Silver have been obtained through talks with Peter Johns and Clare Harrison, Middlesex University. Further information on Argentium™ Sterling Silver is available on URL: http://www.argentiumsilver.com/

Further information on this research project can be found on URL: http://www.mdx.ac.uk/subjects/ad/aar/staff/niedderer.htm