



MOKUME ANOTHER WAY

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INTRODUCTION

Mokume gane is a difficult technique with roots in Feudal Japan. Initially, it was an artistic technique focused on objects d'art and traditional sword furniture. In the past several years, thanks to some enterprising students at the university level, as well as a few designers, it has become a jewelry technique. It is considered by many to be one of the ultimate skills to have as a small-scale manufacturer, and larger scale manufacturing has experimented but found limited success.

The technique involves laminating three or more layers of two or more metals together, which are then twisted and carved to yield patterns. The resulting laminate is then manipulated using traditional jewelry making techniques such as forging, fabrication, and die striking.

Much of the mokume manufactured today is used to make rings, most of it for bands sold as wedding rings. These rings are the main focus of this paper, which outlines a manufacturing method quite different from that of the traditional method of preparing flat stock and then forming rings from it.

BACKGROUND

At the 2013 Santa Fe Symposium®, Paul Nordt presented a paper entitled "Creating Special Jewelry Materials by Hot Deformation Bonding,"¹ which demonstrated Nordt's ability to produce multi-layer tubing of various sizes and lengths. These extrusions are typically large and costly.

After seeing this excellent presentation, I decided to share the method we have been using for over a decade to produce smaller scale tubing in a small shop setting. It's based around cold deformation, specifically deep drawing of precious metal laminates. While it certainly does not have the benefit of the mass production scale of which the John C. Nordt company is capable, it does allow for combinations not achievable in large-scale co-extrusions.

Why?

Quite simply, mokume gane rings are difficult to make. They are also nearly impossible to size up without introducing non-patterned materials or to size down without the removal of material, adversely affecting pattern alignment. Additionally, mokume rings made from flat stock have the disadvantage of either having a visible seam or requiring additional manufacturing steps to cleverly

conceal the seam. Sizing seamless mokume gane rings is relatively simple, accomplished by annealing and either stretching or reducing on a ring-sizing machine (Kagan, Durston or Pepe) or a Klink machine.

OBJECTIVES

- Laminate and reduce billets
- Using deep draw techniques, create multi-layered tubing
- Pattern ring
- Finish

Necessary Tools

Most tools used are easily found in the well-equipped studio; however, there are tools that are not found in most studios that are necessary for this method:

TEMTP or other torque plate system

Hydraulic press (We use a 55-ton press from Bonny Doon for the billet preparation, the deep draw, and the smoothing of the patterned relief.)

Deep-draw tooling designed for 76.2 mm x 3 mm disc

316 Stainless steel foil

Activated charcoal

Electric kiln large enough to contain stainless steel foil bagged TEMTP system

Powered rolling mill

High-speed micromotor hand piece

LAMINATE AND REDUCE BILLETS

We laminated three billets, each comprised of 38.1 mm round discs. Starting materials thicknesses varied from billet to billet. We have found higher layer counts desirable for seamless rings, as patterning cuts do not need to be as deep.

The first billet was the popular 14K palladium white gold and silver. We used nineteen 1 mm layers, with both top and bottom layers of .925 silver. This metal combination has also been used in many of the Santa Fe Symposium® papers on mokume gane.

The second billet was 14K red gold and silver. We used nineteen 1 mm layers, with both top and bottom layers .925 silver.

The third billet was very similar to one of the three-metal combinations of which we sell large amounts—14K red gold, 14K palladium white gold, and .925 silver. Consisting of 37 layers, it was composed of alternating layers of 0.8 mm 14K red and 14K pw gold, with 0.5mm layers of .925 silver inserted between every layer of gold. Top and bottom layers were 14K pw gold.

Billets were laminated in the TEMTP system. This system consists of plates, bolts, die cavity and die. Please see the Santa Fe Symposium® proceedings from 2005 for more details on the construction and design of these systems. ²

The system we used was made from A286 and 718 stainless steel; torque plates were A286, with die, cavity, and bolt studs of 718 (Figure 1).



Figure 1 Round TEMTP A-286 plates, 718 cavity, dies and bolts

Cleanliness is very important to the bonding process, and we cleaned the sheets prior to loading the TEMTP system using the following method: Sheets were first visually inspected for defects and then cleaned using mounted Scotch-Brite™ (Figure 2) and a polishing lathe at 3450 rpm. After cleaning both sides, the sheets were hand scrubbed in distilled water with Simple Green® and a Scotch-Brite pad. The sheet was held under the distilled water in the first of the three tubs, removed to be scrubbed with the Scotch-Brite pad and Simple Green, rinsed in the same tub, rinsed in the second tub and inspected to make sure the water sheeted off evenly prior to being placed in a third 'holding' tub of water containing a pinch of citric acid. This is a very common cleaning method.



Figure 2 Initial cleaning with mounted Scotch-Brite™ buff

The sheets were then removed one by one and dried using lint-free disposable towels and stacked on a clean surface. After all sheets were dried, they were loaded into the TEMTP die.

The loaded TEMTP system was then placed into a 316 stainless steel foil bag with activated charcoal. This bag provides a reducing atmosphere. The bag was then placed into an electric kiln and fired for two hours at 696° (1285°).

After cooling, the billets were removed and inspected before being placed between torque plates and put back in the kiln at 696°C (1285°F). After an hour, the billets were removed and hot pressed to 80% of their starting size (Figure 3).



Figure 3 20% hot-press reduction

After cooling, the billets were reduced by 20% in the 450-ton press (Figure 4). This step is a much easier method than forging the billet by hand, which is also acceptable. The billets were then trimmed back approximately three millimeters from the edge to remove the edge and any possible contamination.



Figure 4 450-ton press

Finally, the billets were processed to 3 mm plate in a series of rolling and kiln annealing steps, with 20% reductions taken after each annealing. The rolling mill we used is pictured in Figure 5. Once the billets had been reduced to 3 mm plate, 76.2 mm discs were cut from the plate. These plates were annealed and set aside, ready for drawing into tubing.



Figure 6 Rolling mill used for sheet reduction

Note: We are lucky to have a rolling mill that opens quite wide, so we can begin processing billets by rolling sooner than most small shops equipped with smaller mills can. Most of the smaller mills available to the studio jeweler open to ~6 mm. In order to prepare the billet for these mills, a combination of more hot pressings and/or cold hand forging could be used.

DEEP DRAWING

Deep drawing is a sheet-metal forming process in which a sheet-metal blank is radially drawn into a forming die by the mechanical action of a punch.³ It is a shape -ransformation process with material retention. The process is considered 'deep' drawing when the depth of the drawn part exceeds its diameter. This is achieved by redrawing the part through a series of dies. This deep-drawing technique can be used to either preserve the sheet thickness or to reduce wall thickness (a process known as ironing).

A series of dies and punches are designed with several criteria in mind: the size of the starting blank, the desired interior diameter of the finished tube, and the number of steps necessary to not damage the materials being drawn from that start to that desired finish. Our set is pictured below (Figure 6) and consists of six steps and extraction tools for removing the drawn part from the punch.



Figure 6 Deep-draw tool set

The annealed 76.2 mm discs were loaded onto the die, and the punch was placed in a tool holder/die shoe. This is a die shoe we produced in house to help keep the operation centered (Figure 7). All parts were lubricated with a suitable lubricant; we like to use Boeshield® paste lube (Figure 8). There are many choices, from lard to automotive grease, but the Boeshield has the advantage of a relatively clean, low-temperature burnoff that is also low in volatile organic compound (VOC).



Figure 7 Die shoe used to align deep draw tooling in press



Figure 8 BOELUBE® Paste

Then, with relatively low pressure (well below five tons), the 3 mm plate quickly becomes a cup shape (Figure 9). After this initial draw, the plate was formed into a cup shape. It then needed to be removed from the punch in preparation for the next draw.



Figure 9 First draw of 3 mm plate forming cup shape

The extraction system consists of a plate with graduated holes to accommodate the punches, a threaded rod and crank handle, and a piece of tubing that acts as a standoff. With just a few twists of the handle, the deep-drawn cup is easily extracted (Figure 10).



Figure 10 Extraction of the cup from the punch

Annealing is not necessary at every step, and in fact, over-annealing is not recommended. Successive draws follow this methodology, with the previous die acting as a guide for the next die (Figure 11), until the desired interior diameter of the drawn part is reached, in this case 15.8 mm (the same as that of a size 5 ring).



Figure 11 Second draw setup. Note top die being used as guide.

PATTERNING

Tubing can be patterned and then ironed to form ring tubing. But, frankly, after much experimentation, we've never found patterns we like this way. They tend to be very coarse and drawn out. More experimentation should be done with this method, however, as it would be a very quick way to produce rings.

In our shop, we rely on patterning of the individual ring blanks, using multiple methods. In most cases we remove material and then smooth the blank. We do also use a punch-down method, followed by removal of the layers standing above the punched-down areas.

First, however, the deep-drawn shapes need to be prepared. We took our cup from the final deep-drawing step to a 5C collet lathe without annealing. There we trimmed off both the top and bottom edge of the cup (Figure 12). The top edge is scrap, while the bottom edge may be reserved for patterning practice or perhaps even manufactured into jewelry. This leaves a clean-edged tube (Figure 13).



Figure 12 5C lathe being used to cut off the end of deep-drawn shape



Figure 14 Laminated tubes ready for parting off

Once we trimmed the ends, we could then part off blanks as wide or as narrow as we desired. We have found that in order to end up with a 6 mm ring, we need to start with a slightly wider blank, approximately 6.5 mm. Figure 14 shows the tubing parted off into ring blanks.



Figure 14 Rings ready for patterning

For patterning that involves material removal, we work inside a reclaimed polishing hood setup as a carving station. Burs are stored in a drawer below, and the micromotor hand piece is routed through the old spindle hole (Figure 15). The ring was placed on an inside ring clamp so patterning could begin (Figure 16).



Figure 15 Carving station for patterning



Figure 16 Ring mounted on clamp for patterning

We use a series of rounded burs of many sizes to pattern our blanks, depending on the effects we wish to see in the finished ring. Additionally, you can machine, hand file, chisel carve, or even engrave patterns in the material.

Once patterned, the blank can be left with topography (called guri bori) or it can be flattened to create mokume gane. Figures 17-22 show cut-down patterned rings ready for flattening.



Figure 17 Cut pattern ring 1



Figure 18 Cut pattern ring 2



Figure 19 Cut pattern ring 3



Figure 20 Cut pattern ring 4



Figure 21 Cut pattern ring 5



Figure 22 Cut pattern ring 6

Flattening can be accomplished by several methods. Prior to any of these steps, the ring must be de-burred and annealed.

First, we used a radial bristle disc to de-bur the exterior of the ring to keep bits of metal from being forged into the ring. Then, we were ready to flatten the ring using one of many methods. The simplest is with a hammer and mandrel. This is a slow process, especially if one desires a smoother ring surface. It is possible to make both flat and rounded rings this way. Once the shape is close to perfect, it is a simple matter to clean up the exterior with light filing or abrasives. This changes the pattern very little if you have done a good job of planishing.

Another method, which yields smoother exterior surfaces that require little work prior to finishing, is to use the flat dies of the Kagan Ring Roller (Figure 23) or a Klink machine if you are lucky enough to have one.



Figure 23 Kagan Ring Roller

A third method we've devised irons the ring on a tapered mandrel into a constraining die. The die holds the ring and the tapered punch drives metal outward (Figures 24 and 25). The ring is placed into the die (Figure 26), and two plates hold it in place, top and bottom. After ironing, the ring is pressed out of the die with the help of a brass punch (Figure 27).



Figure 24 Ring ironing die set



Figure 25 Ring-ironing die set mounted in press, inverted for tapered punch removal



Figure 26 Ring held in center die



Figure 27 Brass removal tool in place to push ring out of die

The disadvantage to both the Kagan Ring Roller and our tapered die set is that they create rings with flat tops. Klink machines use a rolling action and contoured dies, making it much easier to create rounded surfaces.

The punch-down method of patterning differs in that punches or stamps are used to deform spots of the ring blank. This can be done by hand (Figure 28) or by use of the press buddy with the optional dapping kit and mandrel kit (Figure 29). Once designs have been pressed into the ring, the high spots are filed or turned back on a lathe while the contour of the ring is created simultaneously.



Figure 28 Punch-down patterning by hand

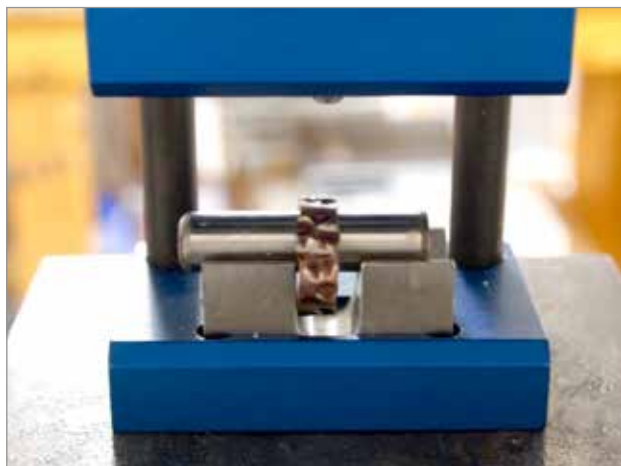


Figure 29 Punch down patterning with press buddy

Regardless of the method of flattening you choose, you are rarely left with the correct ring size. However, the seamless mokume gane ring allows for easy reduction and enlargement. Care must be taken with guri bori designs to not damage the topography (especially when reducing), otherwise additional smoothing may be required. To size, simply anneal and then reduce or enlarge the ring. We use several commercially available ring stretcher/reducers. We have had best results, when stretching or reducing, by not exceeding more than two full sizes without annealing. Once the ring has been sized, the edges are cleaned up to the desired width on a small lathe (Figure 30).



Figure 30 Dimensioning a patterned ring on a lathe

FINISHING

For the best finish, mokume gane is brought to a high polish using traditional abrasive steps and compounds. Then, use wet medium Scotch-Brite™ with a drop of dish soap to produce a matte finish; this surface shows the pattern the best. Additionally, if the pattern contains silver layers, it can also be easily etched to further enhance contrast. Figures 31-36 show some mokume gane rings made with the methods outlined in this paper.



Figure 31



Figure 32



Figure 33



Figure 34



Figure 35



Figure 36

REFERENCES

1. Paul W. Nordt III et al., "Creating Special Jewelry Materials by Hot-Deformation Bonding," *The Santa Fe Symposium on Jewelry Manufacturing Technology 2013*, ed. E. Bell and J. Haldeman (Albuquerque: Met-Chem Research, 2013).
2. James Binnion et al., "Designing, Building and Testing a Thermal Expansion Mismatch Torque Plate System for Diffusion Bonding Mokume Gane Billets: 'The Poor Man's Hot Press'", *The Santa Fe Symposium on Jewelry Manufacturing Technology 2005*, ed. Eddie Bell (Albuquerque: Met-Chem Research, 2005).
3. Daniel B. Dallas, *Pressworking Aids for Designers and Diemakers*, 1st ed. (Society of Manufacturing Engineers, 1978).