MOKUME GANE WORKSHOPS

Mokume (moe koo may) **Gane** (gah nay) is a metalsmithing technique developed by 17th century Japanese swordsmiths. Influenced by Chinese lacquer work, they used their metallurgical knowledge to bond together sheets of non-ferrous metals (similar to the pattern-welded steel) in order to create sword furniture and fittings. The technique went through many name changes but eventually was termed, mokume gane or “eye of the wood grain metal”. It was not until the early 19th century that Japanese artisans began using mokume gane in other decorative objects. Soon with the advancement of the industrial age, it became an obscure process, but managed to survive by being taught at Tokyo University.

Today it is still taught in Japan and has become a well-known metalsmithing technique here in the United States, thanks in large part to Hiroko and Eugene Pijanowski. Their first exposure to the technique was in Tokyo at a traditional Japanese craft exhibition in 1970. The beautifully patterned surface intrigued them enough to find out about the process. Once back in the states, they along with other metalsmiths conducted research on traditional aspects of making diffusion bonded mokume gane.

Traditional Diffusion Bonded Mokume Gane

Mokume Gane can be made by sweat soldering sheets of alternating metals, but this process can be frustrating, time consuming and yield very little workable material. Using traditional Japanese ideas with modern equipment can result in a much better outcome. There are three key components to making a successful mokume gane billet:

1. The stacked metal must be clean and free of any surface oxides or contaminates.
2. The stacked metal must be held under very tight pressure.
3. The stacked metal must be heated consistently to ensure proper bonding.

To put it simply, at least 2 different metals in sheet form are thoroughly cleaned, alternately stacked, clamped together in steel plates, and heated until the layers fuse together. The stack is heated to the point where an alloy is created between each layer of metal. This alloy or interlayer is strong enough to hold all the layers together to make a billet. The billet can be worked down into a unique and beautifully patterned piece of sheet metal or made into ring stock. And just like most non-ferrous metals, it can be formed, manipulated, and soldered.

Equipment needed to fire a proper billet

- 18-24 gauge sheet metal (good combinations: fine silver/copper, sterling silver/copper, copper/fine silver/shibuichi, fine silver/shakudo, 14k palladium white gold/sterling silver)
- programmable electric kiln
- stainless steel foil
- activated charcoal pellets

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- 2- steel torque plates 1/4”-1/2” thick with holes drilled in each corner
- 4- high grade steel bolts and nuts
- c-clamp vice grips (holds the plates and stacked metal together while taping)
- 20-ton hydraulic press (if not available hand tighten using bench vise and adjustable wrenches or torque wrench)
- wood/brass cleaning jig
- 3M scotchbrite cleaning blocks
- Simple green degreaser
- citric acid pickle
- pumice powder
- masking tape
- white out or yellow ochre
- utility knife
- lint free towels
- air blower (optional)
- proper safety equipment (glasses, gloves, long pants, ear plugs, clothes-toed shoes)

Preparation

Starting with a billet made of either sterling silver or fine silver and copper is recommended. They are relatively inexpensive, bond well, and have similar working characteristics. Use 18-24 gauge sheets, no larger than 1” x 1.25” and no less than 12 layers. The metal should be hand cut to give a nice flush edge with no bevel. If a bench shear is used the edges need to be filed to eliminate the beveled edge. Make sure the sheets fit in the cleaning jig and recut or file if necessary. If the metal is not dead soft anneal, pickle and rinse. Next check for deep scratches or pits. If there are any deep blemishes discard or use that piece on the top or bottom layer. Also check to make sure each piece is flat-no wavy metal. Sand each sheet with 320 grit sandpaper. This will help reveal any deep scratches or pits. Now, it is time to really clean the metal.

The following steps should be done immediately preceding the firing of the billet. Starting with the silver, scrub the surface of each square with a scotch-brite block loaded with simple green and pumice powder. Use the cleaning jig-clamping it to a table will make it easier. Be sure to handle the metal by the edges or wear latex gloves. Rinse and leave soaking in clean container with cold water and citric acid pickle. Next clean all copper sheets using a fresh scrub block. Keep the metal as clean as possible! Dropping on the floor or touching the surface means you will have to start the cleaning process over again. After all metal is clean and soaking in the pickel, remove one by one with tweezers and dry both sides. Place on a clean lint free towel. If water spots are present, dip back into pickle water and re-dry. This is one last chance to check all surfaces for deep scratches or pits. If any piece of metal is suspect put aside and it can be used on the top or bottom of the stack.

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Stacking
Before stacking, coat the surface of the torque plates with yellow ochre or white out. This will keep the stack from sticking to the steel. Carefully stack the sheets of metal-handling only the edges if not wearing gloves. Check to see the metals free from lint (an air blower can come in handy for this) as each sheet is stacked, and that each is alternating. Two like metals will not bond to each other. Once all the metal is stacked use c-clamp vise-grips to compress and hold the metal while wrapping a layer of masking tape around the edges. Before removing from the vise grip press tape firmly around the edges. The tape will remain on throughout the firing process.

Next use a hydraulic press to compress the taped stack-max it out. Transfer the stack to the torque plates, making sure it's centered while hand tightening the bolts. If available, use an automotive torque wrench to tighten the bolts to at least 30 ft. lb, otherwise use a large adjustable wrench. Tighten each bolt slightly and then move diagonally opposite to until all four are tightened fully. Make sure the torque plates are parallel on all four sides. The masking tape should be visibly puckered. The stack is now ready for firing.

Firing
Firing a billet in a programmable electric kiln moves away from low tech, but it makes bonding difficult metals at high temperatures possible and reduces risk of overheating if using a torch or furnace.
Using the stainless steel foil make a pillow shaped pouch with two creased and folded sides and one open side. The foil is sharp so gloves are advised. Open the pouch and fill ⅓ full with the activated charcoal. The torque plate assembly goes in next (making sure it will eventually sit flat on the bolts inside the kiln) and then remaining charcoal. The pouch opening is then folded and sealed.

For copper and silver the kiln is set between 1350-1375 degrees F and fired for 6 hours. Place the pouch inside the kiln, program the controller, and start the firing cycle. Remove the pouch from the kiln. If it's still hot, wait until it has cooled. The kiln should be back on and set again to 1300 degrees. Carefully remove the torque plate assembly from the pouch. In most cases the charcoal can be used again, but not the pouch. Take apart the torque plates by removing a few bolts. The fused billet now needs to be “set”. This is basically a light round of forging while the billet is visibly medium red in color.

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Forging

Equipment needed for forging the billet:

- 20oz-32oz. forging hammer (heavier for those with more arm strength)
- 14” pick-up tongs or vise grips
- anvil
- belt sander or angle grinder
- rolling mill
- proper safety equipment (glasses, gloves, long pants, ear plugs, clothes-toed shoes)

This next step, forging will determine if proper lamination has occurred. A few forging sessions can be done before grinding or cutting off the uneven edges. About 1/16” or 1.5mm is removed to help prevent delamination at the edges and to see the definition of layers. Setup an annealing station-several clean refractory bricks arranged to make a “cave”. Creating a dark area will help to see the dull red color when annealing. It can also be done in the electric kiln using the same firing temperature. Do not forge a billet containing sterling silver if it is still red hot-wait until it has cooled and turned dark, or also called black hot. A billet with fine silver may be forged at dull red to speed up the thinning process.

Since the billet is too thick to put through most rolling mills, hand forging will have to be done instead. Use tongs or flat vise grips to hold the billet on an anvil or anvil surface. Typically a 1 to 2 pound hammer is adequate for forging these metals. Start hammering around the edges towards the center. The billet will have a nice dull sound when striking –this means good lamination. Be sure to anneal the billet often, and do not quench. If cracks and splitting occur trim off that area and resume forging. Again it is important to anneal often but do not overheat.

Patterning

There are two methods for making patterned sheet metal- bumping or chasing and carving. For the bumping method roll the billet to 16-18 gauge. Use different punches and chasing tools to bump one side of the billet-it can be anchored in pitch or a block of wood for more stability. Keep in mind the shape of the punch determines the look of the pattern. To reveal the pattern grind away the bumps with files or a belt sander. Be careful not to over bump the metal or grind too much-this will cause holes to appear. After the grinding is done a rolling mill is used to even out the sheet and get the desired thickness. To hide any remaining dents solder a thin piece of metal on the back.

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The second method used to pattern is carving or removing metal from the top layers down. The billet is thinned to 8-10 gauge using a rolling mill to ensure consistent thickness. Anneal and anchor the billet to a block of wood using small screws-one on each side. The flex shaft with grinding burrs can be used to carve through the first 3-4 layers. Run through the rolling mill until there is a shallow mark from the initial carving. This will act as a guide for the second round of carving. These steps are repeated until the desired pattern is achieved. Another subtraction method uses a drill press and larger size high speed twist drill bits. Again anneal the billet and anchor to a block of wood. A good size drill bit to start with is 3/16". The goal is to drill through the first 3 layers, using just the tip of the drill bit. Since a drill bit is round the pattern will eventually be a concentric ring pattern. Again roll thinner until there is a shallow divot. Leaving the divot will make it easier to drill in the exact same spot. And again these steps are repeated until the pattern is developed and the sheet is flat. A rule of thumb to remember when patterning-starting with a thicker billet will result with thicker sheet metal. Starting at 8-10 gauge will result in 18-20 gauge patterned sheet.

Another way to get an interesting pattern is to cut off a section of the billet, about ¼" thick. Hammer the rod to elongate to 1 ½" but keep it square. Anneal the rod, put one end into a vise and start twisting. Anneal a few more times and keep twisting until it's nice and tight. The rod can then be forged back square or put through a rolling mill. The outside twist pattern is nice, or cut the rod down the center to reveal an even more interesting pattern.

Seamless Rings

Instead of cutting into two pieces a seamless ring can be made using some forging techniques. After the stock is made square determine how long of a slot to cut through the center. Refer to the chart at the end of this handout. At each end of the slot drill a hole with a #60 drill bit. Its important to drill holes straight through the stock and not at an angle. Using a drill press will help drill precisely-a hand held flex-shaft will not work. After the holes are drilled the slot can be cut using a larger size jeweler's saw blade (#4). Be sure to cut a straight even line so each side is the same thickness. Now the slot can be opened with a center punch or chisel end chasing tool. The ends can be hammered with a mallet to open the slot so it will fit on a ring mandrel. At this point the goal is to shape the ring round and to keep it the intended size. Use a metal hammer, but be careful not to stretch the ring to a larger size. Some interior filing can be done in order to make an inside liner fit snuggly. In fact the liner should fit so tight that it has to be hammered in place with a mallet.

An alternative to this method is to make a washer (½" opening and 1" diameter) from 18-16 gauge patterned sheet. A disc cutter and center tool will do the job or use a circle

template to draw on the metal and hand cut. The next step is to dome the washer in a dapping block-to its smallest dome. After annealing it can be shaped on a ring mandrel to widen the smaller opening (originally ½”). The goal is to take make the form parallel-a band ring. This will result in a size 9 ring, approximately. A hollow ring can be made using a ring sizer/shrinker. This will give it a domed look, but will also make the ring smaller in size. The last step is to fabricate a sterling silver liner. A wide band ring is made using hard solder. The mokume ring should fit tightly over the liner and then soldered with medium. (Reminder: A small drilled hole in the liner is necessary when soldering a hollow ring form.)

For more information on Mokume Gane refer to these sources:

Websites

- Mokume Gane Workshops
  https://www.mokumeganeworkshops.com/
- Santa Fe Symposium Papers
  http://www.mokume-gane.com/documents/SantaFePaper.pdf
- Steve Midgett’s book online
  https://www.mokume.com/book

Books

Mokume Gane, A Comprehensive Study by Steve Midgett (out of print)
Mokume Gane by Ian Ferguson (out of print)
Textbook of Mokume Gane by Masaki Takahashi
Color, Texture & Casting for Jewelers by Carles Codina (2 chapters on Mokume)

Suppliers

- Reactive Metals
  https://www.reactivemetals.com/mokume-gane-alloys
- Sakmar Enterprises
  http://www.sakmarenterprises.com/home
- McMaster-Carr
  https://www.mcmaster.com/