Fine Cabinet Makers Don't Use Chain Saws*

by Stephen W. Attaway, Ph.D.
November 1997

When Nancy and I began faceting, we were plagued with scratches. It was not until we heard a presentation several years ago by Scott Wilson, Ph.D. that we were able to correct our scratching problems. Scott was an optical component fabrication engineer (now he builds machines that measure the size of the fine lines found on computer chips). To obtain the exact shape of a mirror, he used an ion beam to remove very thin layers and correct the surface contour of the mirror to within a small number of atoms in thickness. Any subsurface damage would cause problems for his ion beam process, the evidence showing as pits and surface defects that became progressively worse as material was removed from the surface. The ion beam process literally "uncovered" the subsurface damage and left it exposed on the surface of the mirror.

In his talk to the New Mexico Faceters Guild, Scott discussed techniques for measuring damage caused by the grinding process. Using special optical techniques based on light scattering from internal fractures, Scott and his colleagues were able to estimate the depth of the damage caused during grinding. He showed that grinding damage could extend approximately 4 to 10 diameters of the grit size below the surface.

This damage can only be removed using the next smaller grit size. For example, if you are grinding with an 220-grit lap, (0.06 mm. grit diameter) approximately 0.6 mm. must be removed to insure that no damage is hiding below the surface. Enough material must the removed with each finer grit to insure that all the damage from the previous grit is ground away.

Often, the micro-cracks caused by the grinding process are not visible. The cracks will be there. However, they will be very hard to see because no stress is holding the cracks open. Scott showed examples of optical flats used in the ring laser gyroscopes that form the core of the navigation system on jet aircraft. The surfaces appeared to be perfectly polished when examined under a normal microscope. Using his light scattering technique on what appeared to be a perfectly polished surface, the damage from the sawing and grinding process was clearly visible underneath this nearly perfect surface.

Think about when scratches occur. They appear when you are doing the final polish, applying lots of pressure. If the stone is not perfectly flat with respect to the lap, it is quite possible that a small chunk of damaged material can break loose from the stone and roll across the surface of a facet.

Ever since we began thinking about removing the damage layers left by the previous grinding steps, we do not get any scratches. Getting a good pre-polish means more than just grinding at 1200 or 3000 grit. It means working each grit (i.e. 80, 220, 600, 1200) to remove the damage made by each grinding step. If a grit step is skipped, then the next smaller grit will need to be worked much longer to ensure the proper removal of damage.

Here is an estimate of the damage layer thickness for each grit size (using 4X as the minimum and 10X as the maximum) (For more info on grit sizes see the Gemstone & Mineral Data Book by John Sinkankas).

Damage Layer Thickness For Different Size Grits

Grit size	Thickness (mm)	
	Min	**Max**
80	1.04	2.6
180	0.34	0.86
220	0.24	0.60
325	0.12	0.30
600	0.06	0.16
1200	0.03	0.07
3000	0.01	0.03

Often, the coarser grits take more effort to clean up than any time they might save in material removal.

Now, you ask, how can I get a fast cutting lap at these grit sizes?

The Optimal Lap

In addition to the grit size, several other factors affect the depth of the damage layer generated during the grinding process. For example, the grinding force, the lap rotation speed, the type of lubricant, the type of bond, the backing material, and the amount of diamond in the lap can all effect the cutting characteristics during grinding.

Several different bonding materials are used to bond the diamonds to the lap. The “metal-bond” laps attach the diamond by plating the diamond onto a hard metal surface using a nickel plating process. “Sintered” laps are made by pressing and heating a mixture of diamond with metal powders until the metal starts to melt. The popular Dyna laps are made by mixing diamond with acrylic paint. In the optics industry, a “resin-bonded” lap is used. In these laps, the diamond is held in place with an epoxy-like resin combined with another binder. The tendency in the lapidary industry is to supply harder grades of bonding material under the assumption that they will wear less rapidly. Much smoother cutting, however, can be obtained with a softer lap.

Consider the effect of taking a steel hammer and striking a piece of glass. The high density and high stiffness of the hammer will cause considerable amount of shock in the glass and yield deep cracks. If a rubber mallet is used, then little shock will occur in the glass. A rubber mallet is less dense and not as stiff as the glass. Consequently, it will deform instead of the glass. Likewise, the nature of the bonding material used in a lap will greatly effect the depth of the damage layer generated during the grinding process.

The quantity of diamond in the lap also greatly affects the cutting rate. Obviously, the more diamond there is in a lap, the more points of contact will be at the cutting face, and the faster the cutting rate will be. There is a maximum amount of diamond that one can put into a lap. If we imagine diamond stacked like oranges in a crate, then the maximum amount works out to be roughly 72 carats per cubic inch. Because of economic constraints, most laps have much less than the maximum. If you are curious about just how few diamonds are in contact with your stone, then put your lap under a microscope and count the number of diamonds you see in a given area. For most laps, you won't be impressed.

One of the big problems is that it is hard to hold those diamonds in place. If you try mixing some diamond powder with epoxy, you will find that the diamond has a tendency to pop out of the epoxy.

Epoxy does not like to stick to the surface of a diamond. Most lap manufacturers make up for this by adding more binder, meaning less diamond and a slower cutting rate.

I have found one diamond manufacturer, National Diamond Lab (1-817-599-6920), who has solved the problem of how to hold the diamond in place. They coat their diamond with a chromium plating process. The diamond is first coated with a very thin layer of chromium, and a very thin layer of nickel is then plated to the chromium. A very thin copper layer is then plated to the nickel. This series of thin layers is barely visible, however, the diamond is tightly held within the epoxy bond. It seems that some epoxies love to stick to copper. National Diamond Lab presses small ductile copper spheres between the spaces to give added strength and toughness.

I have used resin-bonded tools made by National Diamond Lab for gem carving. With 100 percent diamond in a resin bond, the cut is fast and generates a minimal damage layer. In addition, the high quantity of diamond makes these tools very wear resistant. Unfortunately, National Diamond Lab does not make laps for faceting. Inland Diamond Products (1-800-347-2020) does make resin bonded labs. Inland manufactures a diamond grinding system used to make lenses for eye glasses. They also made a variety of other diamond products. I tried Inland's resin bonded "lap-caps". These are six inch laps that have a PSA backed liner that you can press onto a worn out lap. They cut relatively fast and generate little damage. However, in the finer grits, they did not have as much diamond as the products supplied by National Diamond Lab. Consequently, the high-pressure of a grinding a small stone could significantly mark grooves in the laps. In addition, the lack of 100 percent diamond means that they will not cut near as fast.

I'm still looking for the perfect lap. Unfortunately, the large manufacturers of diamond products view the lapidary industry as too small a market. The biggest market for diamond products, surprisingly, is the re-polishing of floors. One representative at 3M estimated the cost of re-polishing marble floors at three dollars per square foot. Just like our stones, the stone floors require working with multiple grits. Now, just think about where all the big banks spend their money....getting a good polish with a minimum of damage.

*The title of this article came from a comment made by Jonathan L. Rolfe on Faceters' Digest. I had posted the grit size table on Faceters' Digest, an internet forum for faceting. His analogy was just to good to pass up. Thanks, Jonathan.