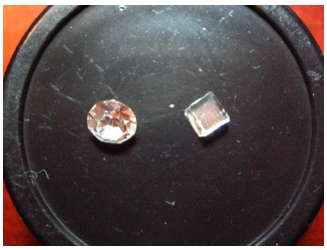
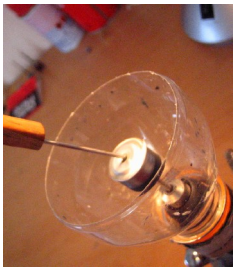
A NOVEL METHOD FOR MAKING MINIATURE LENSES

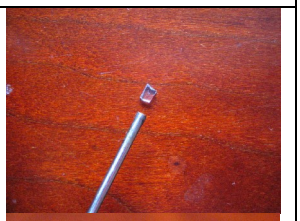
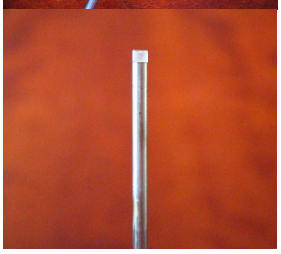
By Alvaro Amaro de Azevedo - May 2007

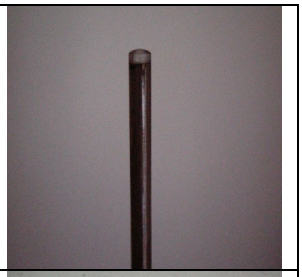
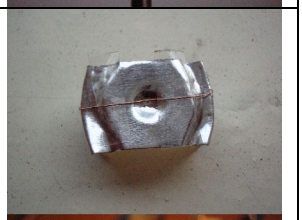
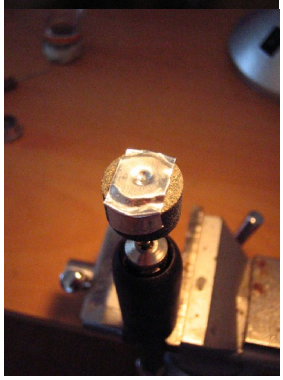
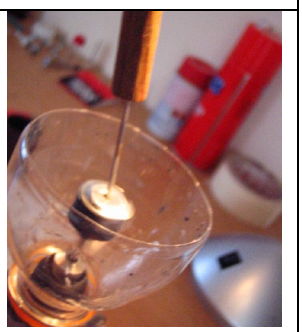
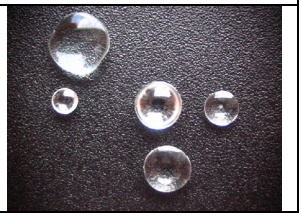
Introduction:

The process to be described below could well be regarded as a good example of "Darwinian evolution" through natural selection. From its humble origin to this presently evolved form, a chain of evolutionary changes was set in motion by an interminable sequence of trial and error assays, each causing unforeseen mutations. Features that made it better have survived and those which did not, underwent extinction. The surviving product of this evolution was "the fittest" for use. Therefore, despite the technique may look an intelligent method, it wasn't a fruit of "intelligent design".

Main Materials			
10 µm diamond powder 	1 -2 µm diamond paste 	0.15 mm thick aluminum Foil 	Set of spindles 
Grinding Lathe 	Glass sources 	Hot Balsam (Home brewed) 	Tool with its guard-rail 
Aluminum Sheet 	Copper Wire ~ 0.1 mm 	Polishing pad 	Jeweler's loupe 

Nr.	Other Materials
1	Aluminum plate 1.0 mm thick
2	Vaseline grease
3	Glass cutting tool
4	Sand paper 80 grit and 220 grit and/or diamond file
5	Various sizes of steel balls from different ball bearings
6	Hot Glue stick

Step	Process Description	Picture
1 Making the Tool	To create the tool, cut a 15 mm circle out of the aluminum plate, place it against a piece of hardwood and press a steel ball of the chosen diameter right in the center of the disk with the help of a vise or press. This will create a spherical dimple that should be wider than the lens diameter. Glue this disk to the top of a Dremel grinding stone tool and make sure it is well centralized.	
2 Making the Blank	Heat up the handler of choice and melt a small amount of hot balsam cement. Stick a small square of glass not much larger than the rod's diameter. Centralize the piece and let it cool down. Grind the edges against a wet sandpaper until a regular cylindrical shape is formed. Make then a bevel to protect the edges from chipping away. The pictures shown aside correspond to a blank and spindle 1.5 mm wide made from a small squared piece of glass microscope slide cut by the author. The thickness is 1.0 mm.	 
3 Grinding	Place the spindle-tool in the dremel machine connected to a power source having half of the normal power supply. It can be made by using a 110v to 220v transformer connected the all way around. The motor should be kept steady and vertically positioned with the help of a vise. Place a piece of aluminum foil and make it to take the shape of the tool by gently pressing it against it with the same steel ball used before. This part is named liner. Add a very little bit of diamond grit to the dimple and add some grease. Turn on the motor and set it for a very slow speed (100 rpm). Hold the handle between the fingers and place it leaned in order the workpiece to be in contact with the rotating dimple. As the tool rotates, slip the fingers to rotate the handle in the opposite direction of the tool's motion. Swing the angle of inclination of the handle so to ensure a perfect curvature is being generated. From time to time, clean the workpiece and inspect it with the help of a 10 times magnification jeweler's loupe. Keep grinding until no flat area is noticed in the workpiece. The surface should be regular and well curved at this step. For the sake of letting a less rough surface, just apply less pressure during the final grinding after the workpiece has already taken the intended shape. Operat-	  

	ing this way will smoothen the surface similarly as it would happen if using fine abrasives grits, but taking much shorter time.	
4 Micro-grinding	This is where this method most diverges from conventional lens making processes. Remove the first liner dirt with diamond grit and grease. Clean the tool, place a new aluminum foil and repeat what was done before to prepare the grinding step making a new liner. Now add a copper wire across the diameter of the dimple. Fix this wire in position using adhesive tape in its extremities. This wire is named scraper. Lay an aluminum sheet the same size as above in the top of this tool and press it gently the same way. This aluminum cover foil is named "wig". Now that the micro-grinding set is arranged, place a very small blob of diamond paste in the top of the cleaned workpiece and start the motor again. Proceed as in the grinding step adding a little bit more pressure to the handle as it is moved. After 30 seconds or so, inspect the workpiece where a glossy surface should already have been formed. Inspect the dimple and see if the scraper is still in position. A section of this wire should be visible and uncovered by the wig as its trajectory scrapes the face of the workpiece. This is a crucial part to the good output of this step and if the scraper slipped out of position it should be brought back and a new wig applied. If everything is gone OK, proceed for a few more minutes and set the motor to higher speed (1000 rpm). At the end of this stage the surface quality should be superior to the finishing given by any conventional method but there is still one step more to completion.	  
5 Polishing	Place two small squares of optical paper for cleaning eyeglasses in the top of the worn wig and apply a small blob of diamond paste. Repeat the procedure as above for a while using lower pressure than in the previous step. Let it polish a bit further and inspect to see if the surface has reached its final optical transparency. No scratches, pits or defects of any kind should be noticeable after this process was thoroughly accomplished. The workpiece should look clear like a drop of water.	
6 The other Side	For biconvex lenses, the workpiece must be detached and glued in the all way around letting the flat face up. Then, all the procedure described above should be repeated.	

Final Notes and Conclusion

As for any handcraftsmanship or hobby, this method also requires repetition and persistence in order to be fully mastered, but is far simpler to be learned than its "pre-Cambrian" ancestor.

Using liners, will make the tools last virtually forever so one can make a set of tools with different curvature radii and be able to generate a wide variety of lens profiles. The liners however are disposable and should not be used more than once or twice.

When the edges persist to stay rougher than the center, the solution is to add more layers of aluminum sheet to the top of the wig and proceed polishing. This will extend the polishing action to the imperfect edges of the lens.

The home brewed cement used by this author was made by combining 80% Brazilian Cherry tree resin with 20% bee's wax. This resin is taken from *Hymenaea courbaril* which is similar to the temperate climate copal resin.

Given the quantities used in each lens making process and since there is no waste, the diamond paste from a 5g syringe should last for a life time, so as the diamond grit.

Cutting small glass squares may be not as easy as it looks like. One can also shatter a small piece of plane glass and choose a chard that suits best but this will require taking all necessary safety precautions to prevent injuries these chards may inflict if improperly handled.

The motion of the scraper seems to subject the workpiece to a micro-grinding action in which material is removed under ductile regime. It's known that ductile abrasion can remove material without creating micro-cracks. Because polishing would solely smoothen the sharp edges left behind during coarse grinding, the underneath layers with a network of microscopic cracks cannot be eliminated. This causes the surface to reach a high degree of smoothness and shiny appearance but not to be highly transparent. Micro-grinding however, can obliterate the roughened outside layers and keeping removing underneath cracked strata formed during the brittle regime of coarse grinding until all damaged layers have been removed. Conventional lens making techniques can eventually led to surfaces of very high quality, but it will require a lengthy and painstaking process consuming considerable time. The presence of unremoved micro-cracks will ultimately scatter light lowering the quality of the image and overall performance of the lens. The simple introduction of a material removal under ductile regime using the scraper can suppress the undesired layers at a fraction of that time. The evidence that supports this claim lies in images observed from a bright punctual light source. Lenses made by other techniques show foggy and halo surrounded images, while those made by this ultimate method show minimum if any halo at all. One notices nearly no flare and highly contrasting crispy sharp images of subjects under transmission light observation, feature that hasn't been possible previously with ordinary lens making method.

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"Man has always to be busy with his thoughts if anything is to be accomplished."
Antony van Leeuwenhoek (1632 – 1723)

* The last paragraph reflects the author's own interpretation of the phenomenon based on his understanding of the existing knowledge and systematical observations not representing a definitive description. This note should be seen as a personal view rather than as a statement.