The Science of Working with Glass Alchemy, Ltd. Boromax® Colors

By Henry Grimmett

Glass Alchemy, Ltd. is proud to be on the forefront in the development of new colors and methods in the borosilicate art field. As a young company we have made the choice to invest in research rather that slick advertising. Prior to the pioneering work at Glass Alchemy there was little reliable information available. People couldn't get their silver colors to strike, colors would turn "muddy", "go take a class" or "your flame can't be oxidizing". Nobody had a method for adjusting the flame to a neutral position and verifying it. Even today it is still common to hear phrases like "burn in the silver" or "burn the silver in with a reduction flame".

In Part 1 and Part 2 of *The Flow* magazine series of articles we talked about setting up your torch so that you can achieve a neutral flame, and we have discussed how to evaluate the flame and make corrections. We have explained the "hows and whys" of the basic color components and some "best use" practices. In this and the following article we will explore working each color. As you read about the various colors please keep in mind that the spirit, effort and research at Glass Alchemy has created most of the colors used in borosilicate today. The bright crayon colors were first developed by GA and still remain the widest selection and highest quality on the market. The Chrome Aventurine (sparkle) colors were first developed by GA and tested two full years prior to introduction and contain what we feel are the largest flakes available in an extremely stable base. The Turquoise series represent the finest and most continuous opal series on the market. And as you read about the 300 series colors you will discover that there are many options available as you design your silver containing color to achieve your desired end result. You will discover that all of our colors were designed with you, the artist, in mind, solving real problems that have been presented over the years. If you have not yet tried Glass Alchemy Boromax®, I hope that you will. Not only has GA created revolutionary new colors but has continuously improved production techniques which allow the manufacture of very consistent, straight, round cane in 4mm, 7mm and 10mm cane. Now working the glass...

When creating a piece many elements go into the design. Consideration is given to the overall size, what colors, the order of attachment and so forth. Often the color choices may include some of the more serendipitous ones such as 786 Triple Passion. When using one of the "color changing" types, the preferred method is to build the complete piece in a hot, neutral flame. After the piece is assembled then go back and bring out the properties of the colors. More will be said about these metals throughout the article.

Glass Alchemy, Ltd. created its numbering system to provide information to the artists to make their design decisions easier. Based on the spectrum of the rainbow, the 100 series are the reds, 200 series are the orange, and the yellows are the 300's followed by the greens in the 400 series. The 500s represent the blues while the 600s and the 700s are the indigos and violets. Commonly called the ROY G BIV method, this provides the artist with an easy way to identify the color. The 800 and 900 series are reserved for neutral browns and black/white colors respectively.

The second or middle number indicates the primary colorant so that the artist can anticipate what the final result may look like as well as make decision on how they may want to work. For instance, a "1" in the center indicates that cobalt is the main colorant, while an "8" indicates that silver is the main metal used to color the glass.

Finally, the last number gives the artist some insight to the chemistry. A low number generally indicates less colorant while a high number indicates more colorant saturation. If the color name has a numeral at the end of the name, this is a clear indication of the level of metal coloration. Remember that in ionic colorants (Part 2 in the series) the higher the concentration of colorant the denser the color.

It often has been asked, what is the difference between a luster, carnival and amazon color? Primarily it is one of scale. On a scale from 1-5 the lusters are 1-1.5, the carnivals are 2.25-2.5 and the amazons a 5 in chemical saturation. There is simply more "stuff" in the amazons than the carnivals. The lusters are the most subtle, while remaining very colorful. The Amazon Lagoon is a special cause. This was designed with the "serendipity" crowd in mind. As GA provides more information on how to "control" the color there have been those artists who remind us they like discovering something new every time they open their kiln, they don't want to control the outcome. For them GA has created the ultimate "plaything" in 587 Amazon Lagoon. GA has introduced thousands of nuclei into each rod and so loaded the glass with silver that it is beyond control. It will respond to every breeze in the room. Have fun with it!

Setting the Neutral Flame

To test for a neutral flame Glass Alchemy, Ltd. recommends heating a stick of 987 Amazon Night to a warm orange glow and allow to cool. If the stick is a light sky blue or has a metallic sheen, the flame is reducing and needs to be adjusted. Reduce the propane content. If the stick is sky blue, it is a very reducing and can only be adjusted by reducing the propane pressure at the regulator, usually by 1/2 the pressure (ex. from 2 to 1 pound). If the rod is metallic, adjustments of the regulator of 1/4 pound increments should result in a neutral flame. Ideally the rod should be the same color coming out of the flame as it was going into the flame.

100 Red Series

The 104 and 106 are crayon colors. *Code: the "0" in the middle position always indicates that the primary colorant is cadmium. Health Warning: Cadmium is a heavy metal that sublimes at a temperature below the optimal flame working temperature, so when working with cadmium colors always work in a well ventilated area (mechanical, positive or negative).*

Working zones. The blue rod on the left indicates where most work is done. The yellow rod on the right indicates how much further out to work a crayon color to help prevent sublimation.

To prevent cadmium colors from subliming into a gas, work the rod farther out in the flame, encase it or adjust the flame to a cooler setting. You can adjust to a bushier flame which is cooler because not all of the propane (C_3H_8) burns or an oxidizing flame because the flame tends to be more turbulent and is rich in oxygen which is cooling the flame.

If you do sublime a small patch of color, it is possible to fire polish the section which will smooth out the glass. The "patch" will be colorless allowing the color from below to become visible, in effect "repairing" the area. Once the glass is applied to a larger piece it generally can be worked more aggressively. The larger piece acts as a "heat sink" and pulls away from the crayon color helping to prevent sublimation.

The 104 is the color richest in unbound cadmium and therefore requires the greatest skill. The 106 is a darker, "iron oxide" red and is bound with selenium and much easier to work. The 106 is closely related to 804 Chocolate, which is the easiest cadmium to work.

The 132, 135, 138, 139 are copper reds. *Code: The "3" in the middle position indicates that the primary colorant is copper. Health Warning: Copper also puts off toxic fumes when melted (in the reduced red form the melting point is about 19840°F) so use only in a well ventilated area.*

Copper is an ionic colorant. In different valence stages (there are three), copper provides different colors due to the distortion in the shape of the molecule. To obtain the red color a percentage of the copper is reduced to the native state. Not all of the copper in the rod is reduced; therefore working the color with a reducing flame can deepen a red color or working with an oxidizing flame can introduce dark (green, even blue) lines into the red color. The difference between the 138 and 139 is the percent of copper that has been reduced at the factory. The 139 Cherrywood is an opal ruby (more copper has been reduced, but not enough to provide a metallic sheen as is found in the 132 Jasper Red which is a similar formula with even more copper reduction) while the 138 Ruby Strike is a transparent ruby (with less reduction).

This series demonstrates the steps in striking. #1, build the piece hot to keep all crystals melted. #2, shows the completed piece prior to striking. Note that some color has already started to develop due to slow cooling of the piece. #3, striking in the back of the flame where the temperatures are much cooler. Note that the flame was not adjusted to be oxidizing or reducing, it is the same neutral flame that the piece was built in. #4, after striking for about 4 seconds. This piece was placed back into the flame for an additional 10 seconds and made to grow blue crystals by the student providing the Demo.

182 Blush is a heavily reduced copper with some silver added to create a sheen on the surface of the glass. This color should be flash heated in a bushy reducing flame to a slight orange glow to create the sheen on the surface after the piece is completed.

All reduced copper colors (copper ruby family) should be worked in a neutral to oxidizing flame. The opal rubies can be worked in a variety of flames to add "character" to their final appearance. All rubies need to be oven struck to bring our their red color otherwise they will have a salmon hue to them. GA colors are designed to strike at 1075°F for one hour +/- 20 minutes. Shorter striking will yield less red while additional striking will darken the color. Flame striking or oven striking at higher temperatures is not recommended for rubies. (See Part 2 in *The Flow* article series on crystal growth in copper rubies.)

161 Erbium Pink. *Code: The "6" in the middle position indicates that the color is a rare earth tint. Health Warning: Use only in a well ventilated area.*

Any flame, any heat. This tint color can be used over a white to create a pastel pink, over other opals as an encasing to change the reflected color, or gathered into large masses such as in marbles or sculptural shapes to yield a vibrant transparent pink. Currently these seeds (small air bubbles) are part of the product, however, GA is continuing to work on methods to fine all of the air all of the time.

163 Electric Flamingo. *Code: The "6" in the middle position always indicates that the color is a rare earth tint. Health Warning: Use only in a well ventilated area. Contains no radioactive material.*

Any flame, any heat. This is a clear stick. It does not strike to any color, it remains clear. It does convert UV radiation to a bright pink color. The UV bulb must be of the BLB (black light blue) type and should be less than one year old. The larger the mass to brighter the color will be. Also this color exhibits fiber optic properties; when looking at the ends of a cane under a BLB light, the ends where the light exits is much more intense than in the rod itself. This novelty color has been used in large murrini, goblets, marbles, beads and pipes.

200 Orange Series

204 Orange and 206 Burnt Orange Crayons. *Code: The "0" in the middle position always indicates that the primary colorant is cadmium. Health Warning: Cadmium is a heavy metal that sublimes at a temperature below the optimal flame working temperature, so when working cadmium colors always work in a well ventilated area (mechanical, positive or negative).*

See 104 and 106 for working tips. Color lots vary with the barometer. The burnt orange is very easy to work while the orange needs to be worked at lower temperatures.

263 Atomic Kumquat. *Code: The "6" in the middle position always indicates that the color is a rare earth tint. Health Warning: Use only in well ventilated areas. Contains no radioactive material.*

Any flame, any heat. This is a clear stick. It does not strike to any color, it remains clear. It does convert UV radiation to a bright orange color. The UV bulb must be of the BLB (black light blue) type and should be less than one year old. The larger the mass the brighter the color will be. It is in the rare earth colors that the fiber optic properties of the glass are enhanced; when looking at the ends of a cane under a BLB light, the color of the ends where the light is stopped is much more intense than in the rod itself. This novelty color has been used in large murrini, goblets, marbles, beads and pipes.

287 Amazon Bronze. *Code: The name "Amazon" indicates a chemical saturation level of 5. The "8" indicates that the primary colorant is silver. Silver is a heavy metal, and it can accumulate in your body.*

"Overloading the body's natural eliminative systems with silver causes the body to store some excess silver in the face; this over time can result in a pronounced gray complexion. Argyria is strictly nontoxic, cosmetic condition. However, argyria is quite serious in that

it is thought to be permanent, much like a tattoo." Quoted from www.silversolutions.com.

The other major colorant is reduced copper. Use only in a well ventilated area. 287 is heavily saturated with silver and copper and can have silver/copper wire running through it. Treat this color as you would treat fuming. In addition to ventilation you should use a shield or HEPA respirator.

This is a fun color to work with. Work very hot in a neutral to oxidizing flame; the base color is a copper ruby recipe. Flash in a reducing flame prior to placing into the striking kiln. The color will be a bright red with rainbows of metallic sheens. The piece will have an "antique" look as it comes out of the kiln with many "spots" of pure copper and silver metals present. The color was created for this "non-glass" look. Use a buff wheel and silver polish and the piece will become very reflective and the metallic sheen will be enhanced. Prolonged kiln striking intensifies the metallic sheen and darkens the red color. Mixing with 592 Brilliant Blue produces colors of the Southwest desert; soft purples and pinks; this is one of our more popular frit colors.

300 Yellow Series

301 Acid Yellow, 302 Rasta Gold and 304 Yellow Crayons. *Code: The "0" in the middle position always indicates that the primary colorant is cadmium. Health Warning: Cadmium is a heavy metal that sublimes at a temperature below the optimal flame working temperature, so when working with cadmium colors always work in a well ventilated area (mechanical, positive or negative).*

See 104 and 106 for working tips. The 301 Acid is a bright yellow with excellent working properties. Mix with 3 to 5 parts clear to make a translucent yellow that "glows" and has many applications. The 302 Rasta Gold has striking properties. As it is melted and worked the color turns to a honey yellow color. Often used in Homer and Bart murrini. 304 Yellow is a "school bus" yellow with some orange in the color. The original "crayon" color, it has gone through many reformulations and is much more workable today than it was during the early releases. It is recommended to work this color further out in the flame.

381 Warm Yellow, 382 Solara, 383 Silver Strike 3, 385 Silver Strike 5, 386 Purple Luster, 388 Carmel Luster. *Code: The number "8" in the center indicates that the primary colorant is silver. Also, the name "Luster" indicates that the surface can develop sheen. The source of the sheen is silver. When silver is not mixed with another colorant, it is placed in the yellow category due to the fact that the smallest silver crystal creates a yellow color. Silver crystals always grow in the same sequence, from yellow to orange, red, red-purple, purple, blue and finally green. Health Warning: Use in a well ventilated area. 385 Silver Strike 5 is heavily saturated with silver and can have silver wire running through it. Treat this color as you would treat fuming. In addition to ventilation you should use a shield or HEPA respirator.*

All silver colors should be worked at hot temperatures to create, form and assemble the elements. Once the piece is formed use reduced (lower) heats, just above the annealing temperatures, say 1075° to 1125°, to heat treat the entire piece to grow all of the silver crystals. The smallest crystals are invisible with the next size creating a yellow color. In order of increasing size the silver crystals will become orange, ruby red, red-purple, purple, blue and green. Depending on how even your heat is and what you do to mix in un-even heat you can create a mix of colors. Such simple techniques as twisting the rod as you heat, touch with a cool paddle or pinching with a pair of needle nose pliers can create great patterns, especially in beads. Also consider using the glass itself as an insulator such as clear frit, or "dots" using other silver colors or tints.

If you want to bring a luster to the surface, raise the temperature of the flame about 75 degrees (remember that it is easy to burn a fume off the surface) and treat the surface about 20 seconds in this busy, reducing flame. This flame will strip oxygen from the silver oxide (silver is reduced with heat, un-burned carbon will transport liberated oxygen away) leaving a metallic silver on the surface causing the "sheen". Consider polishing the surface to enhance the brightness.

A final note about silver colors, they are not created equal. Some formulas have nuclei in them, others don't. Just like a rain drop doesn't form without a speck of dust or a pearl without a grain of sand, nor does a silver crystal grow without something to grow on. GA understands this and has added nuclei to most of its silver colors to make them easier to use. There are those times however when the artist wants more control, so we also have those colors in which you, the artist, can create the nuclei in the amount and at the time you want them. In a color like the Silver Strike 3 or 5, when you are ready simply cool the color to a light orange glow, about 975°F, and hold at this temperature for 20 - 30 seconds and then heat back up to 1075° - 1125° and grow the crystals. The longer you hold the piece at the lower temperature, the more nuclei will be created and the more intense the final color will be.

A reducing flame per se does not create the colors. Crystal growth and color development is a function of time and temperature. A reducing flame will only treat the surface and can create a metallic sheen.

381 Warm Yellow has crystal growth inhibitors to impede the change of color. For many applications the color will remain yellow, however, hard working or prolonged kiln work will cause the crystals to grow. Used by many to achieve purple where another choice may yield a blue because of the working conditions and time.

382 Solara also has crystal growth inhibitors but is designed to work easily into the orange-yellow to orange-ruby aspect of silver to remain transparent. This is a very "hot" color. Overworking may push it into the purples, blues and greens.

383 and 385 Silver Strike have no nuclei. Reducing flame will easily bring metals to the surface of the 385. These colors can be worked very hard but require cooling to a slight orange glow to create nuclei on which to grow crystals if you want to create a rainbow of color. (See Part 2 in the series for more information on crystal growth.)

386 Purple Luster is loaded with nuclei and balanced to cause the color to go straight to a purple sheen. This is an unusual color in that it is an A-B-C color. We ship it to you as a B (yellow) and when it first enters the flame it strikes purple (C) and on the next reheat it strikes clear (A). If you place it in the kiln as a B (yellow) state, it will strike purple. If you place the color in the kiln as a C (purple), it will strike to a very dark purple, almost black. If you place it in the kiln as an A (clear) color, it will do nothing; the temperatures are not hot enough to strike to the purple state. In the flame, if you have struck to from B to C (purple), you van move the glass in-and-out of the flame to keep it at a warm orange glow to darken the purple to very dark shades.

388 Caramel Luster has an additive that causes the glass to always transmit orange and red light. Hobnails on beads or bobbles catch the light and create dazzling patterns on the walls. This color should hand in every window. The glass luster is very modest and achieved with a reducing flame to strip the oxygen from the silver on the surface of the glass thus yielding metallic sheens.

400 GREEN SERIES

403 Chartreuse, 406 Olive Crayons. *Code: The "0" in the middle position always indicates that the primary colorant is cadmium. Health Warning: Cadmium is a heavy metal that sublimes at a temperature below the optimal flame working temperature, so when working with cadmium colors always work in a well ventilated area (mechanical, positive or negative).*

Chartreuse is a very workable green-yellow. In stringers it tends to "yellow" out. Encasing in 510 Cobalt Lite or Brilliant Blue can mitigate this. See 104 and 106 for additional working tips.

406 Olive is a great earth color and is often used as a transitional color or background color. See 104 and 106 for additional working tips.

441, 442, 444, 445, 446, (546), (548). *Code: The "4" in the middle column indicates that the primary colorant is chrome. Health Warning: Chrome is a heavy metal and is on lots of lists. In most forms it is a poison, in some forms cancer causing. These colors should always be worked only in well ventilated areas. In addition chrome puts off a very bright white flare and excellent eye protection is required. One of the reasons that eye protection for borosilicate has increased over the last several years has been due to the introduction by Glass Alchemy of these colors.*

The turquoise series are a chrome based opal color (Coming soon is the Chameleon Series, which will also be chrome based), that if worked incorrectly can be problematic. To avoid problems the torch must be set up properly to achieve a neutral to oxidizing flame. A reducing flame can cause cracking in chrome colors. See both Part 1, on torch set-up and Part 2 on cracking in chrome in this series for more details. The 441 Mint, 442 Sage, 445 Turquoise, 446 Agua Azul along with the 546 Peacock and 548 Twilight from the blue series are very creamy and easy working and work on both inside and outside. 445 Turquoise has been laced with a touch of copper, which develops wisps of Indian Red. Try designing a piece using 445 with 132 Jasper or 106 Indian Red.

The 444 Clover is an older formulation and to retain the color cannot be modified very much, therefore, it has to be worked with much more care. If the 444 is going to be worked hard at higher temperatures and then going to be subjected to on-going high heats as the balance of the piece is shaped and worked for hours, then consider encasing the color prior to use. If 444 is going to be exposed to prolonged periods of a reducing flame, consider encasing first. Do not use this color as a "dot" in a deep encased situation, especially on a curve such as a bottom of a vase.

If holding these colors in the kiln for an extended period it is best to "garage" at 975° rather than at the annealing temperature of 1075°F, due to the risk of creating aventurine at elevated temperatures. We have seen this cause breaking and shearing.

421 Phthalo Green, (521 Pythalo Blue), (531 Teal). *Code: Originally the number "2" in the center indicated that the primary colorants were a combination of cobalt and copper. This convention was dropped after numbering 421 and 521. 531 Teal is also a mix of copper and cobalt. Health Warning: Copper puts off toxic fumes when melted (in the un-reduced green form the melting point it about 2418°F). Use adequate ventilation.*

These are beautiful, pleasing transparents that bring out the best in glass. They both transmit and reflect light, which makes glass a unique medium. While they can create great dots, they make spectacular sculptural colors. Care must be taken not to reduce the the copper to a red valence state. While this is reversible by adjusting the torch, it can be difficult to correct if the piece is "fragile". Make sure to test your flame for "neutral" prior to working.

481 Spring Luster, 485 Green Carnival, 487 Amazon Jewel, 489 Aquatic Carnival. *Code: The number "8" in the center indicates that the primary colorant is silver. Also, the name "Carnival" means that the surface can develop sheen from both silver and copper. The green in these colors is from un-reduced copper. When silver is mixed with another colorant it is placed in the category of the other colorant. The color of the glass that the silver is "viewed" through changes the "hue" of the colors for example the purple color from silver can appear as vermillion, taupe, or plum depending on the the base color of the glass. Health warning: Copper puts off toxic fumes when melted (in the un-reduced greed form the melting point is about 2418°F). Amazon Jewel is heavily saturated with silver and can have silver wire running through it. Treat this color as you would treat fuming. In addition to ventilation you should use a shield or a HEPA respirator.*

These colors should be worked like any silver containing color. (See the 300 series, silver bearing colors and Part 2 of the series.) These rods all contain nuclei on which to grow color crystals, so they are all very easy to strike, even for the novice. Because the the carnivals contain copper, if reduced, they can provide an orange to salmon-to-red color in addition to the hues provided by the silver. The Amazon Jewel contains sparkle in addition to the silver and is very popular when a rainbow of colors is desired. The sparkle is most pronounced when thinned, covered in clear or used for inside work.

481 Spring Luster is a silver color in a light green copper base. The color is not considered a carnival because there is not enough ingredient to create an independent luster from copper. The copper can still produce red streaks if you are working in a reducing flame so be sure to test your flame for neutrality. After working the piece at hot temperatures to create, form and assemble all the elements, use reduced heats just above the the annealing temperatures, say 1075° to 1125°, heat treat the entire piece to grow all the silver crystals. If you want to bring a luster to the surface, raise the temperature of the flame about 75 degrees (remember it is easy to burn a fume off of the surface) and treat the surface about 20 seconds in this busy, reducing flame. This flame will strip oxygen from the silver oxide (silver is reduced with heat, un-burned carbon will transport liberated oxygen away) leaving metallic silver on the surface causing the "sheen". Consider polishing the surface to enhance the brightness.

485 Green Carnival, 489 Aquatic Carnival. The copper content is much higher in the carnivals than the lusters. They work the same as the lusters but orange and red highlights from the copper will also be present. Due to the high copper content the color can become quite streaky in a reducing flame, therefore insure your flame is neutral to oxidizing.

487 Amazon Jewel. This color is part of the "sparkle" series. Like all amazons it is a "5" saturation. The amazons easily have 5 to 10 times the amount of silver, copper, cobalt or whatever of a luster/carnival color. Work it like a luster, expect magnified results.

In the next article we will pick up the remainder of the green colors all the way through the blacks including 5 new colors that are currently in the final stages of testing.

Summary:

1. For the brightest, smoothest crayon colors work in a cooler flame, either by moving out 1.5 inch or cool the flame. You can also encase the crayon colors.
2. Generally use a neutral to oxidizing flame on all colors for the cleanest brightest results. Only use a reducing flame to bring silver metal to the surface.
3. Chrome colors are easy to work with if you avoid working in a reducing flame.
4. Avoid using colors with heavy colorant content next to other colors with a high colorant content.
5. To keep your cobalt colors a bright blue work in an oxidizing or neutral flame, avoid a reducing flame.

In the next issue of The Flow, Henry Grimmett will summarize the remaining Glass Alchemy color palette. These will include the 400 Green, 500 Blue, 600 Indigo, 700 Violet, 800 Brown and 900 Neutral Series.