

The Science of Working with Glass

Alchemy, Ltd. Boromax® Colors

By Henry Grimmett

In the last installment I reviewed the working properties of the 100 through 300 series colors along with some of the greens. In this article, I will finish with the remaining green colors and will cover the 500 through 900 series.

For those that are new to Flow Magazine I would like to review how to determine if you have a neutral flame. First, take a rod of 987 Amazon Night and heat 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 very reducing and can 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. By doing this simple test you can eliminate a host of problems including preventing greens from turning red, chrome greens from cracking (most of it anyways), cobalt from turning grey and silvers from going muddy. Now back to the colors...

400 GREEN SERIES

410 Emerald Lite, 421 Phthalo Green, 431 True Green, 436 Dark Emerald. Code: The "2" indicates that the primary colorants are a mix of cobalt and copper. The "3" indicates that the primary colorant is copper. The "1" was a mistake and now we are stuck with the number. It does indicate that the color is a tint and in this case it is a copper tint. Health warning: Copper puts off toxic fumes when melted (in the un-reduced green form the melting point is about 2418°F). Use adequate ventilation.

In terms of chemical saturation, 410 is a "1", 431 is a "2" and 436 is a "3". Each is a doubling of the one in front of it in the list. The higher the copper content the denser the color and the tendency to develop red streaks increases in a reducing flame. Transparents 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 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.) These colors are very easy to work and offer a range of analogous transparent greens. The 421 is related to the 521 Phthalo Blue and 531 Teal.

461 Kryptonite. Code: The "6" indicates that the primary colorants is a rare earth. The chemical saturation of all rare earth colorants is 5. Praseodymium (the colorant) is an ionic colorant, therefore the thicker the application the darker the color. Health warning: Same as for clear glass, "Use in a well ventilated area."

Rare earth colors can be used as tints over other colors to create subtle shifts in reflected and transmitted light. Over white they create pastels. Gathered into marbles the color starts to become quite intense. Kryptonite becomes a lime green when gathered to an inch or more. Consider this color for fish bodies or large jelly fish. Or use this tint to encase other colors to change their reflected color properties. Also looks nice used in stems for glassware.

458 Green Sparkle, (588 Teal Sparkle). Code: The number "5" in the center indicates that the primary colorant is reduced chrome, precipitated out of solution as a metallic platelet. Health

Warning: Chrome is a heavy metal and is on a lot of lists. In most forms it is a poison, in some forms cancer causing. These colors should be worked only in a well ventilated areas. In addition, chrome puts off a very bright white flare and excellent eye protection is required.

These colors should be worked in a neutral to oxidizing flame. While much has been done to stabilize the chrome to prevent unwanted aventurine growth and cracking, it is the artists responsibility to mitigate the known issues when working with chrome colors. "Tugs" on this color will stretch this color and align the platelets to improve the level of sparkle. Also, it is known that when working with clay that it is necessary to align the platelets. In clay you "pull-out" parts rather than "add-on" otherwise there is no cohesion. For adding on there are techniques for aligning the platelets when it is necessary to "add-on". Not much is written about the use of aventurine glass as it relates to frameworking. When adding-on in glass, we recommend a wipe-on/(wipe-off) technique rather than straight seals at 45/90 degrees. End-to-End seals should be quite hot and pressed together and then pulled/stretched to align the platelets. GA makes this recommendation because we have noticed that Mother Nature tends to be consistent in the rules she gives to us.

500 BLUE SERIES

The blue in all of these colors comes from cobalt. Cobalt can produce grays in a reducing flame. This can be pronounced when the glass cools to a very light orange and then placed back into a reducing flame. If you experience gray cobalt, test your flame for neutrality and if a reducing flame is required keep the work hot rather than allowing it cool below 1400°F.

510 Cobalt Lite, 512 Cobalt 2, 514 Cobalt 4, 515 Cobalt 5, 516 Cobalt 6. Code: The "1" indicates that the primary colorant is cobalt. (The only exception is the 410 where the "1" indicates that it is "lite" or tint.) Cobalt is an ionic colorant, therefore the higher the cobalt content the denser the color. Also, the thicker the application the darker the color becomes. The higher the number at the end of the name the greater the cobalt content in the rod. Health Warning: Cobalt is a heavy metal and inhalation of cobalt fumes can cause shortness of breath, coughing and pneumonitis. Hypersensitivity appears to be involved because lung changes occur at low incidence and are varied in intensity and time of onset. In most cases, the symptoms disappear. Cobalt is listed by ACGIH as an animal carcinogen. Cobalt is known to the state of California to cause cancer. Use only in well ventilated area.

Cobalt blue has always been one of the most appealing colors in glass. GA blues are made from finely milled cobalt's mixed into small particle batches and then mixed in three separate processes to insure an even distribution to produce the most consistent rod. Because a teaspoon of cobalt can release up to 7 liters of oxygen during the manufacturing process GA uses a proprietary technique to fine (remove) the air from the glass without over-fabricating the glass which can cause it to be "sketchy" in some applications.

Cobalts are also infra-red emitters. Because of this they require more energy to melt and they cool much faster so that they work "stiff". To mitigate the stiffness of Cobalt 5 and 6 GA has added a flux that softens the glass in the temperature range of above 1800°F.

546 Peacock, 548 Twilight. Code: The "4" in the middle column indicates that the primary colorant is chrome. Health Warning: Chrome is a heavy metal and is on a lot of lists. In most forms it is a poison, in some forms cancer causing. These colors should 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 is chrome based, opal color 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 Flow Magazine article series for more details. The 546 Peacock and 548 Twilight are very creamy and easy working and work on both the inside and outside. 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 1050°F. You should not hold these colors (or strike other colors in the same piece) at temperatures above 1075 F, due to the risk of creating aventurine at elevated temperatures.

585 Teal, 587 Amazon Lagoon. Code: The number "8" in the center indicates that the primary colorant is silver. The name carnival indicates that the color contains both silver and copper in amounts enough to luster. When silver is mixed with another colorant it is placed in the color category associated with another 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 a vermillion, taupe, or plum depending on the base color of glass. Health Warning: Use in well ventilated areas.

585 Teal Carnival is a blue-green color. The copper content is much higher in the carnival 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, if this is not the desired effect, insure your flame is neutral to oxidizing.

The 587 Amazon Lagoon is a special case. This was designed with the "serendipity" crowd in mind. As GA provides more information on how to "control" the color there have been those who remind us they like discovering something new every time they open their kiln, they don't want to control the outcome. For them we have created 587 Amazon Lagoon. GA has introduced thousands of nuclei into each rod and so loaded the glass with silver that it is beyond control. Touch it with your paddle, tweezers, twist it with your pliers, use a can of cold air and blow on it, clear frit ups...go wild with this one.

597 Blue Luster. Code: The number "9" in the center doesn't indicate anything. This number was assigned when we were cleaning up our system. The primary colorant is silver. Also, the name "Luster" indicates that the surface can develop sheen. The source of this sheen is the silver. When silver is mixed with another colorant it is placed in the color category associated with 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 a vermillion, taupe, or plum depending on the base color of the glass. Health Warning: Use in a well ventilated area.

The color should be worked like any silver. After working the piece at hot temperatures to create, form and assemble all the elements use reduced heats just above the annealing temperatures, say 1075° to 1125°, heat treat the entire piece to grow all of the silver crystals. 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 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, unburned carbon will transport liberated oxygen away) leaving metallic silver on the surface causing

the "sheen". Consider polishing the surface to enhance the brightness.

521 Phthalo Blue. 531 Teal. Code: Originally the numbers "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 is about 2418°F). Use adequate ventilation.

These are beautiful, pleasing transparents that bring out the best in the 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 not be taken to reduce 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 prior to working by heating a stick of 987 Amazon Night to a warm orange glow and cooling. If the stick is light sky blue or has a metallic sheen the flame is reducing and needs to be adjusted. Reduce the propane content.

517 Royal Blue, 592 Brilliant Blue. Code: The "1" indicates that the primary colorant is cobalt. (The only exceptions to this are the 410 where the "1" indicates that it is "lite" or tint and 597, 592 were the "9" has no meaning.) Cobalt is an ionic colorant so the thicker the application the darker the color becomes. Health Warning: Cobalt is a heavy metal and inhalation of cobalt fumes can cause shortness of breath, coughing and pneumonitis. Use only in a well ventilated area.

Cobalt blue has always been one of the most appealing colors in glass. These two colors have had their refractive index altered to make them much brighter, and the brilliant blue has been said to dance with the light. They do tend to resist turning gray. This is a great color for all applications but has become particularly popular for coil potting, beads and sea animals. A neutral flame is best.

558 Teal Sparkle. Code: The number "5" in the center indicates that the primary colorant is reduced chrome, precipitated out of solution as a metallic platelet. Health Warning: Chrome is a heavy metal and is on a lot of lists. In most forms it is a poison, in some forms cancer causing. These colors should be worked only in well ventilated areas. In addition, chrome puts off a very bright white flare and excellent eye protection is required.

These colors should be worked in a neutral to oxidizing flame. While much has been done to stabilize this color to prevent unwanted aventurine growth and cracking, it is the artists responsibility to mitigate the known issues when working with chrome colors. (Please do not use a reducing flame.) "Tugs" on this color will stretch and align the platelets to improve level of sparkle. Also, it is known that when working with clay that it is beneficial to consider the alignment of the platelets. In clay you "pull-out" parts rather than "add-on" otherwise there is difficulty in cohesion. For adding on there are techniques for aligning the platelets when it is necessary to "add-on". Not much is written about the use of aventurine glass as it relates to flameworking. When adding-on in glass we recommend a wipe-on/(wipe-off) technique rather than straight seals at 45/90 degrees. End-to-End seals should be quite hot and pressed together and then pulled/stretched to align the platelets. GA makes this recommendation because we have noticed that Mother Nature tends to be consistent in the rules she gives to us.

600 INDIGO SERIES

672 Blue Violet. Code: The "7" in the middle position always indicates that the primary colorant is manganese. Health Warning: Symptoms of manganese poisoning range from sleepiness and weakness in the legs to difficulty walking and uncontrolled laughter. Health surveys of employees exposed to manganese fume have

demonstrated a high incidence of pneumonia in these workers (OSHA). Work in a well ventilated area.

The 672 Blue Violet is a very easy working purple. It is half the strength of the 773 Grape with a slight blue hue, therefore in the 600 series. A neutral flame is recommended.

683 Indigo 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 this sheen is the silver. When silver is mixed with another colorant it is placed in the color category associated with 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 a vermillion, taupe, or plum depending on the base color of the glass. Health Warning: Use in a well ventilated area.

683 Indigo Luster is a favorite with the random trail and rake crowd. Work like any silver color. Great purples due to the fact that the base color is purple. The rods all contain nuclei on which to grow color crystals so they are very easy to strike, even for the novice. Silver crystals always grow in the same sequence: from yellow to orange, red, red-purple, purple, blue and finally green. The luster is very intense in this color and is achieved with a reducing flame to strip the oxygen from the silver on the surface of the glass thus yielding metallic sheens. This is also another favored frit color from GA.

700 VIOLET SERIES

773 Grape, 775 Dark Plum. Code: The "7" in the middle position always indicates that the primary colorant is manganese. Health Warning: Symptoms of manganese poisoning range from sleepiness and weakness in the legs to difficulty walking and uncontrolled laughter. Health surveys of employees exposed to manganese fume have demonstrated a high incidence of pneumonia in these workers (OSHA). Work in a well ventilated area.

773 Grape and 775 Dark Plum are about the same strength but different blends of the same chemicals. They offer different hues of purple. Grape compare to good grape jelly and Dark Plum has the pink/black tones of a plum. The grape tends to provide a more even coat over white. The Dark Plum is available in frit. Both colors coil pot very well with no visible lines. Both appear to be very stable. A neutral flame is recommended.

761 Lavender. Code: The "6" indicates that the primary colorant is a rare earth. The chemical saturation of all rare earth colorants is 5. Neodymium (the colorant) is an ionic colorant, therefore, the thicker the application the darker the color. Health Warning: Same as for clear glass "Use in a well ventilated area".

Rare Earth colors can be used as tints over other colors to create subtle shifts in reflected and transmitted light. Over white they create pastels or try encasing over other colors to change their reflected color. Gathered into marbles the color starts to become quite intense. Lavender becomes a blue under some light, purple (blue with red hints in it) under other lights when gathers to an inch or more. Consider this color for marbles, eggs or stems for glassware.

800 BROWN SERIES

804 Chocolate Crayon. Code: The "0" in the middle always indicates that the primary colorant is cadmium. Health Warning: Cadmium is a heavy metal that sublimates at a temperature below the optimal flame working temperature, so when working with cadmium colors always work in a well ventilated area.

To prevent cadmium colors from subliming into a gas work the rod further 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 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 the 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 heat away from the crayon color helping to prevent sublimation.

The 804 is the color richest in bound cadmium and therefore requires the least skill. The 106 is closely related to 804 Chocolate.

833 Beryl. Code: The "3" in the middle always indicates that that primary colorant is copper. Health Warning: Copper also puts off toxic fumes when melted (in the reduced red form the melting point is about 1984°F) so use only in a well ventilated area.

This old world formula doesn't like a lot of heat. While it does not sublime like a crayon it does release oxygen if heated to around 2000°F. Works well in most flames but it is recommended to use a neutral flame. Try to work in a cooler flame.

860 Warm Brown, 864 Sienna. Code: The "6" indicates that the primary colorant is a rare earth. The chemical saturation of all rare earth colorants is 5. Neodymium (the colorant) is an ionic colorant, therefore, the thicker the application the darker the color. Health Warning: Same as for clear glass "Use in a well ventilated area".

Ionic, these transparent colors can be used as tints or used as solid colors. In a reducing flame they can be shifted to a smoky black. In theory they can be oxidized to a purple. We have not been able to do it however.

900 NEUTRAL SERIES

931 Black (Green). Code: The "3" in the middle always indicates that that primary colorant is copper. Health Warning: Copper also puts off toxic fumes when melted (in the un-reduced green form the melting point is about 2418°F). Use adequate ventilation.

In terms of chemical saturation this color is a "4". The higher the copper content the denser the color and the tendency to develop red streaks in a reducing flame. Care must be taken not to reduce 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 prior to working by heating a stick of 987 Amazon Night to a warm orange glow and cooling. If the stick is light sky blue or has a metallic sheen, the flame is reducing and needs to be adjusted. Reduce the propane content.) This color can be blown out to an amazing forest green color.

974 Black (Violet). Code: The "7" in the middle position always indicates that the primary colorant is manganese. Health Warning: Symptoms of manganese poisoning range from sleepiness and weakness in the legs to difficulty walking and uncontrolled laughter. Health surveys of employees exposed to manganese fume have demonstrated a high incidence of pneumonia in these workers (OSHA). Work in a well ventilated area.

The 974 Black (Violet) is very stable and works well in all flames. It is recommended that a neutral flame is used. We have encountered some situations when this color has reacted with dichro. It appears that when dichro is stretched and the quartz layer loses its integrity the manganese reacts with the metals of the dichro and cracking can occur. The 974 has also been seen to react with the 104 Red Crayons at the margins and separation has occurred. It is still our most popular black and is available in frit.

987 Amazon Night. 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 elimative 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 a non-toxic, 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 cobalt. Use only in a well ventilated area.

This is a fun color to work with, so, work it like any silver color. Work very hot in a neutral to oxidizing flame. Flash in a reducing flame prior to placing into the striking kiln. The color will be a blue or green with rainbows of metallic sheens. Use a buff wheel and silver polish and the piece will become very refractive and the metallic sheen will be enhanced. Prolonged kiln striking intensifies the metallic sheen.

993 Black (Blue). Code: The "9" doesn't indicate anything. This should have been 913, but it was early on when we named this color. The primary colorant is cobalt. Health Warning: Cobalt is a heavy metal and inhalation of cobalt fumes can cause shortness of breath, coughing and pneumonitis. Hypersensitivity appears to be involved because lung changes occur at low incidence and are varied in intensity and time of onset. In most cases, the symptoms disappear. Cobalt is listed by The International Agency for Research on Cancer (IARC) as Category 2B - possibly carcinogenic to humans. Cobalt is listed by ACGIH as an animal carcinogen. Cobalt is known to the state of California to cause cancer. Use only in a well ventilated area.

If you experience gray from the cobalt, test your flame for neutrality. If a reducing flame is required keep the work hot, then don't allow it to cool below 1400°F.

SOME NEW COLORS

The Chameleon Series (4484 Clover Chameleon, 4486 Agua Chameleon, 5486 Peacock Chameleon, 5488 Twilight Chameleon) We have taken some of the colors in the Turquoise Series and added silver. We have even used the old names since the working properties will be similar. The addition of the silver provides all of the colors you would expect, but they have a completely different look because they are in an opal rather than transparent base color. These work great in beads, sculpture and production work.

858 Moroccan Sparkle. This is a most unusual color. Depending on how it is applied it appears either black or brown. It is loaded with sparkle and works very smooth, much like clear rod. If the color is overheated, such as when applying "dots" at white heat, green colors will develop. The rod is "shocky" and should be pre-heated in the back of the flame before bringing it into the working zone.

Summary:

1. 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.
2. Chrome colors are easy to work with if you avoid working in a reducing flame.
3. Avoid using colors with heavy colorant content with dichro, especially high Manganese colors.

Special Thanks

I hope that this series of articles have been useful to you. If you have any questions or contributions, please, do not hesitate to contact Glass Alchemy, Ltd. at 503-460-0545. I would like to give my thanks to all of the testers who have contributed greatly to the understanding of how the colors work. I especially thank Mike Plane for developing the neutral flame test, Nick Bartlett for his testing and insights into the chrome colors. Doug Remschneider for his insights into all of the colors especially cobalt and reduced copper colors. Doug's initial contributions along with Lewis Wilson, both convinced each was working the color incorrectly, first led GA to start teaching a working theory of crystal growth and to explain the role of oxidation and reduction as it relates to the lampworker. Marcel Braun for bringing all of his cracking issues as he pushed back the frontiers with his large projects and "extreme lampworking" techniques. Finally, I would like to thank Laurie Copeland who helped create the Instructors Sample Pack and whose questions helped me to understand some of the difficulties in my presentation style. Thanks to the hundreds of others that have shared information with Glass Alchemy. Flame On!

