Colour gobo patterning process

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Introduction

This paper describes the necessary steps for successful patterning of dichroic colour gobo's manufactured by Drix.

The patterning process consists of five steps:

- Exposure
- Development of the photoresist
- Postbaking
- Etching the chrome layer
- Etching of the dichroic layer
- Stripping of the photoresist
- Stripping the chrome layer

Exposure is done by placing a film on a UV exposure unit and aligning the gobo on that film. Care must be taken that the gobo is in good contact with the film during exposure.
After exposure the gobo is developed. This is done in a alkaline solution. The exposed photoresist will dissolve and the underlying aluminium layer is cleared.
Then the photoresist can be optionally postbaked. If the image needs resolution, this is a recommended step. The postbaking process will harden the photoresist.
Then the gobo is etched in a HF solution. All dichroic material that is no longer protected by the photoresist is etched out, and the image becomes visible.
After etching the remaining photoresist is stripped using a ketone dissolver, eg acetone.

In order to obtain good and repeatable results, several precautions must be taken and good processing technology must be maintained.

Film requirements

Before starting, it must be ensured that a good quality film is made to obtain a well defined image. The film requirements are:

- Pin-hole free
- Dust-free
- Dot size compatible with imaging and etching process
- Good flatness

It is a good practice to make the film in such a way that the dichotic layers are oriented towards the K-part to minimise the distance between the colour layers and the K-part.

Please see the explanation on the B/W process for film properties.

Gobo Exposure

The photoresist is sensitive to blue light and broadband UV. The maximum sensitivity is around 400nm. The energy required to expose the photoresist is approx 100mJ/cm^2.
Please see the explanation on the B./W process for correct exposure.

Gobo Development

Once the gobo is imaged, it can be developed. The developer will dissolve all exposed photoresist. It is very important to keep the developing chemistry stable and to adjust the exposure dose only. To startup a new process, it is important to get started using a known good developer, such as the Arch/Fuji chemicals HPRD402. Developing time in this developer is 90-120 seconds at 20°C. Use 90s for greyscale images and 120s for solid images. Most other commercial developers will also develop the photoresist in the 60 - 120 seconds range.

Please see the explanation on the B./W process for correct development.

Postbaking

This step is optionally. Postbaking may enhance the resolution when necessary.

Postbaking can be done on a hotplate, 10min at 115-125°C. Small hotplates are available from companies selling laboratory equipment. The temperature accuracy needs to be +/-5°C
The surface of the hotplate must be clean. Do not attempt to use a cooking plate as a hotplate, as these are on-off systems which are very inaccurate and will lead to overtemperature conditions.

The postbaking step drives solvents out of the resist, making it harder and improving the adhesion of the resist..

If the temperature of the postbaking step is raised too far, the resist may either start to flow, or it might change structure making it very hard to remove it afterwards. (In extreme cases the only way to remove overbaked resit is an asher, which is a vacuum chamber with an oxygen plasma attacking the resist)

Chrome etch

Drix colour gobo's have a thin chrome layer over the dichroic layers.
The transmission of this chrome layer is 30% typically.
As such, the colour of the underlying dichroic is visible. But beware: the chrome causes a small colour shift so the final colour cannot be measured correctly unless the chrome layer is stripped.

The main purpose of the chrome layer is to enhance etching resolution and avoid humidity-related photoresist problems.

The pattern in the photoresist layer must be copied into the chrome layer. This can be done by inserting the gobo in chrome etchant (the main components are ceric ammonium nitrate and acetic acid). A suitable commercial chrome etchant is Transene type 1020AC.
The etching time is typically 30s-60s. This time is not critical.
You can make your own chrome etchant by diluting 10grams of solid ceric ammonium nitrate into 300ml of distilled water. In solid form is an orange powder.
If the chrome etch is done in a small cup the acid may be depleted quite fast, so then the etching time needs to be prolonged.

Etching of the dichroic layers

Warning : HF is LETHAL in high concentrations and DEATH IS FINAL !

Read the recommendations at the end of this document.

After chrome etching, the dichroic layer must be etched.

Etching of the dichroic layer is done with HF (HydroFluoric Acid) , or with a buffered solution based on HF. (Hydrogen Fluoride). The reason is that HF is the only chemical which is capable of etching SiO_2.

Etchable dichroic filters consist of alternating layers of SiO_2 and TiO_2.

A general problem is that the etching speed in SiO_2 and TiO_2 is never equal. This will leave the edge looking like a staircase after etching.

When the HF concentration is lowered, then the etching speed also drops, but it does not drop equally for both materials. If the concentration is too low, the etching action may stop totally for TiO_2, leading to severe undercutting and loss of resolution.

Generally a higher concentration offers higher resolution etching, but endpoint detection becomes more difficult. Also, a higher concentration is more dangerous.

Endpoint detection is important because the etching of dichoics is very sensitive to undercutting (overetching). The best way to check if the endpoint has been reached is to etch the gobo in a plastic cup over a white light box. When white light is visible in all area's which need to be open, the endpoint has been reached. Some colours are hard to distinguish from white. Yellow imposes a specific problem, as the human eye is very sensitive to yellow. In

such a case it helps to put a filter over the light box of a complementary colour. In the case of a yellow dichroic, a blue or cyan filter may prove very useful.

An etching time in the range of 2-3 minutes usually yields good results.

Please keep in mind that the etching action continues until the gobo is immersed in water. When etching in a small cup, the cup may be rinsed when the endpoint is reached with the gobo still in it.

A good HF concentration for etching Drix Dichroics is 3%. This 3% concentration does not need to be exact. Generally the material is etchable in all concentrations ranging from 2 to 20%. A higher concentration will result in better etching speed and higher resolution. It may also help to clear the residue of the last dichroic layer in case of problems. But using a higher concentration is more dangerous and there is a risk of overetching.
It is generally not possible to etch greyscale (rastered) images in batch, the gobo's need to be etched one by one.

It is possible to mix your own HF etching solution by starting from a commercial solution of 10, 20 or 40%. When starting from 40% (this is widely available) you will need to mix 10ml of HF(40%) with 127ml of water to get a 3% HF solution. Always add the acid to the water. You may elect to make other mixtures in order to optimize the etching.

WATCH OUT WITH 40% HF -DANGEROUS! – TAKE ALL NECESSARY PRECAUTIONS.

Resist stripping

If the etching result is good, remove the remaining photoresist with acetone. The acetone will also remove any photoresist that may be present on the backside of the gobo, resulting from production. Advanced organic strippers can be guaranteed to remove all resist in one time. Acetone is often used as a cheap solution, but acetone has the disadvantage that as it gets saturated with photoresist it will start to redeposit the resist on the gobo. If acetone is used, the tank must be refreshed regularly, or otherwise a two step scenario must be used. In such a two step system, the gobo is stripped first in a dirty bath, and then in a clean bath. After some time the clean bath becomes the dirty bath, the old dirty bath is refreshed and becomes the new clean bath.

Keep in mind that if the resist has been postbaked, it may be harder to remove it.
If it has been overbaked, it becomes impossible to remove the resist.

After resist strip the gobo can be dried in air, by nitrogen or by oil-free pressurized air.
Keep the gobo clean after processing. Do not leave fingerprints on the gobo as these might show up in projection, and as the fingerprint may burn into the glass during projection.
Make sure that the tank is compatible with the stripper used. Some materials are not compatible with organic strippers. Polypropylene or teflone coated tanks will be ok.

Organic strippers are hazardous and must be disposed in an environment friendly way and according to local regulations. For personal safety, use chemical resistant gloves while stripping the photoresist. Always manipulate the gobo by the edges only while processing. Be

aware that acetone imposes a fire hazard. It has a very low flash point and should not make contact at any time with hot surfaces or sparks that may ignite it. Be aware that pure acetone burns without making a flame or smoke and as such a fire may start unnoticed. Make plans in advance of what needs to be done when the acetone bath starts burning. Also, do not store more acetone than allowed by local regulations or by your fire insurance company in order to avoid discussions of liability.

For health and safety reasons, make sure your lab is equipped with a sensitive fire detector, suitable fire fighting devices and sufficient ventilation.

Chrome stripping

After the resist has been stripped, the chrome layer must be stripped.
It is generally a good idea to make a last inspection of the gobo before stripping the chrome. If the gobo has not been fully etched, it is actually possible to put it in the HF again for a short while, with only the chrome layer protecting it.

The chrome layer can be stripped by putting it into the chrome etch again.
Please make sure to remove all chrome. Note the time from start of etch to visible chrome removal and then allow the gobo to remain in the batch for at lease the same time again (double the time to ensure complete chrome removal).

The chrome etching acid will generally not attach the dichroic layers, so there is no danger in overetching. It is very important that all chrome is removed, as a very thin chrome layer will not be visible to the eye, but it will absorb light energy, increasing the temperature of the gobo in projection. Unremoved chrome may lead to product failure!

Assembling the gobo's

Either the colour gobo's are mounted on a larger K-part, or the colour gobo's are mounted on a same size K-part and the whole assembly is mounted into a ring.

In the first scenario, the K-part has the correct outer diameter compatible with the lighting fixture. The colour gobo's are somewhat smaller and are glued onto the K-part.

In the 2nd case, all parts are glued into a ring, which has the correct outer diameter.

There are two methods of glueing.
- The first method is to glue the gobo's with a glue which hardens at high temperature. An oven is needed to harden the glue. This method is recommended. A suitable silicone rubber glue may be obtained from RS-Compontents, partnr 555-588. Such a glue is transparant and will withstand 250°C. The glue can be baked in a hot air oven at 100°C. The use of a needle dispenser is recommened. When not using a needle dispenser, make sure to make only small dots of glue, as the glue will quickly spread out when two glasses are pressed to each other. Six to ten small dots of glue on the glass surface are typical. When glueing CMYK gobo's it is recommended to glue the first colour layer to the K-part, align it under a stereo-microscope with low magnification, and harden the glue for 5 minutes in a hot air oven. After that glue and align the next layer. After the last layer has been glued bake the complete assembly for a

longer time, eg 30 minutes. It needs to be verified that the bonding is strong enough.
Rubber silicone glue has the advantage of remaining a little bit flexibele after baking, so that a different thermal expansion of the glass during exposure will not create excessive stress.
Make sure that the glass is dust-free when glueing the parts together. A laminar flow hood with a HEPA filter may be required to create a small dust-free environment.

- The second method is to use a UV-hardenable glue. In this case part of the edge needs to be kept clear (etched out) to allow the glass to be glued in that location. The glue hardens out under UV light, so a flood UV source is needed. This method will work but it is not recommended, because the glue becomes very hard after curing, and places to glue must be incorporated in the design which adds complexity.

The reverse black material with thin aluminum is ideal for use as a K-part for making full colour gobo's.

Handling and installation of gobo's

Make sure no force is applied on the thin glass.
Make sure no cleaning liquid leaks in between the glasses.
The black surface of the K-past must be placed towards the lens.

Dangers of HydroFluoric Acid (HF)

This paragraph is included to offer some insight and the necessary precautions when using HF. By no means this list is to be assumed complete. Drix is not a supplier of HF. Anyone using HF should completely inform himself/herself about the dangers and necessary precautions using the safety sheets provided by the chemicals supplier, by safety experts and by local regulations and laws.

By no means Drix will accept any liability resulting from the etching of its gobo's with HF.

- When you do not fully understand the dangers that HF implies, do not use it. Make sure all operators which use HF fully understand the dangers and take the necessary precautions.
- Store the HF acid in a place which is locked and not accessible to unaware personell or children.
- HF has the appearance like water. It is dangerous to lose attention and overlook the danger.
- When HF is shipped into your company, make sure that the warehouse people know how to handle the incoming shipment, and make sure it is stored safely.
- Make sure you have the safety sheets from your chemical supplier.
- Make sure there is a plan with things to do/check in case of an accident.
- Be aware that HF penetrates the skin, depletes minerals in the blood and can lead to cardiac arrest. In this sense, it is deadly, even hours after exposure.
- Always wear proper gloves and protective clothing when working with HF.
- Make sure to have an emergency shower in the working area.
- This shower should be usable without spraying water into nearby chemical baths.

- If the tap water is cold, make sure to have heated water on the emergency shower, to allow an exposed person to stand on it for a suitable time.
- Think beforehand where the water from the emergency shower will need to go to. Make sure there is a suitable drain. The emergency shower must be operatable for at least 5 minutes, preferably more.
- When working with HF, make sure there is someone else nearby who can help in case of trouble.
- Be prepared to strip all clothing and go fully naked under the emergency shower. Properly dispose all clothing that has been in contact with HF and treat it as dangerous chemical waste.
- In case HF is spilled on your clothing or body, do not underestimate the danger and take all necessary actions immediately.
- Make sure to have calcium gluconate ointment (gel) at the place where the HF is used. It can be used to reduce the calcium depletion while awaiting further help.
- Check in advance which hospital to go to.
- Do not disturb an operator working with HF. When working with HF yourself, do not allow anyone else to disturb you.
- It is highly recommended to use a good bench suitable for HF etching.
- Make sure to have a good exhaust, so the fumes are evacuated. Think about the way the exhaust is built before installing it. A particular hazard is the concentration of HF in the exhaust duct. The concentrations can be locally much higher than that of the mixture in the bath. Many accidents happen when maintaining the exhaust line.
- The exhaust fan needs to be of a type where the fumes do not come into contact with the motor itself. Otherwise the motor will corrode, and replacement will be troublesome.
- Think about the danger of moisture mixing with concentrated HF in the exhaust line, of the consequences of rain and high winds on the exhaust line.

Some more information may be found here : http://en.wikipedia.org/wiki/Hydrofluoric_acid