Mastering Primers and Ink Adhesion

Your new flatbed is up-and-running and one of your best customers comes through the door with a piece of tempered glass, and they want you to print their logo onto it for a display. Do you confidently say "Sure, I can do it!" or do you turn the job down because you heard that it's nearly impossible to get ink to adhere to glass? We regularly hear from members who are looking to print on some challenging substrates, or they contact us after they have tried — without success — as the ink is chipping off, and they are trying to figure out what they did wrong.

Let's remember something that's important — you're not the first one to run into issues with ink (be it digital or screen print, or paint for that matter) and adhesion concerns. Getting good adhesion is all about the substrate's surface energy and the ink's surface tension. Knowing the composition of the ink in your system and the primers you may need, and knowing the surface energy (or how to determine the surface energy) of the material on which you are printing will lead you down the path of success.

Dyne Level Determinants

Measuring dyne levels is one method of determining the ability of an ink to wet out/adhere to a substrate. Surface energy (or wetting) typically is used to describe the reactivity of the surface of a solid substrate, and surface tension is used to refer to a liquid. The surface tension and surface energy are measured in energy units called dynes/centimeter. A dyne test can be conducted three ways. The first is with a dyne pen — the most common and easiest to conduct, though also most susceptible to contamination. The second is the cotton swab applicator, and the third is the drawdown method. The drawdown method is more likely to occur at an ink manufacturing facility than in a production environment.

To better understand the concept of

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dyne measurements, think of rain water on a freshly waxed car. Rain water (or water in general) has a dyne level around 72 (high surface tension), and a good wax coating on a car will bring the surface energy to around a dyne level of 23. So, we have water with a high surface tension dropping onto a waxed car with very low surface energy, and the result is the water does not spread out and wet the car — instead, it forms round droplets that roll off. Ideally there should be a gap of around 10 dynes between surface energy and surface tension, with the substrate having a higher number than the ink for good wetting and therefore adhesion.

Practice (and Training) Makes Perfect

Whether using dyne pens or cotton swab applicators, proper training for those conducting the testing is important. Evaluating the results to determine the correct dyne level of the substrate takes a little practice to make sure that the results are reliable.

The way a dyne pen or cotton swab applicator (with dyne solution in numbered bottles) works is to mark a line on the substrate and see if the ink beads up (like droplets of rain water on the waxed car), or if the dyne solution wets out and spreads in a uniform wet layer. If you get droplets, then you need to pick a lower number pen or select a lower numbered bottle to dip the cotton swab into. Remember, when using the cotton swab method, never dip the swab from one bottle to the next as you will contaminate the solution — always use a clean swab. When you get the solution to wet out and spread in a uniform wet layer, you have the surface energy of the material and you can determine if you need to use any of the techniques that will be covered in this article for better adhesion results.

The first thing you need to do is determine the substrate. Plastics can be tricky to print and come in a variety of "flavors."

Breaking Down the Basics

While speaking with Bruce Ridge from Nazdar Ink Technologies, he shared an acronym used when developing ink that can also help determine the best ink and substrate for an application. The acronym is SAFE, which stands for substrate (or media); application; finishing (flexible, chemical-resistant, compatible with adhesives, folding, etc.); and, end use (will this product be used outdoors, exposed to extreme heat or cold, etc.)

The first thing you need to do is determine the substrate. Plastics can be tricky to print and come in a variety of "flavors," including polyethylene (PET), high density polyethylene (HDPE), polyvinylchloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS) and "other," meaning other polycarbonate (PC). Following suit as substrates difficult to print on — similar to plastic — are teflon, delrin and silicone. Lastly, glass and metals — including coated and powder coated metals — can present difficulty. What you care about and need to know is the surface energy of these materials (using a dyne test) because a substrate with a high surface energy attracts more than a substrate with a low surface energy.

Per the acronym above, application typically refers to the printer applying the ink. So, for the end user with a UV flatbed, the important takeaway is UV curing power. Are the power levels of the lamps adjustable or fixed? If the former, then you have some flexibility with getting a good and proper cure on the substrate, which will allow you to adjust as needed.

In most digital printing environments, there is only one ink available, so the variable comes down to substrate and primer/adhesion promoters needed to develop a good bond. Some manufacturers will have a couple of different inks that they recommend for their printers depending on the end user's prevalent workflow. For instance, is the printer and ink being used primarily for flexible or rigid applications? Other manufacturers have taken the step of incorporating primer as one of the ink channels. This makes it easier to apply the primer when and where it is needed, reducing the need to apply the primer manually prior to printing. It is important to note most adhesion promoters come in multiple solutions for different substrates — meaning that the universal jettable primer needs to be tested thoroughly.

I reached out to a few different UV printer manufacturers — primarily those that have jettable primers just to share how these work, and when the manufacturers would recommend their use. Josh Hope, Sr. Manager, 3D Printing & Engineering Products, Mimaki USA, and Mark Berglund, VP of Operations, LogoJET, both shared that testing is crucial when printing on difficult substrates. UV inks possess a surface tension in the 25–35 dyne level range, depending on components in the ink. Both Hope and Berglund confirmed their inks fall in that range. They also noted that jettable primers give you the ability to just place the primer where needed,

which also means that some of the primer will be purged during nozzle checks or maintenance cycles.

Prepping the Surface

Keeping in mind the need for a 10-dyne difference for good wetting out of the inks — and using the dyne levels of the inks in the previously noted 25–35 dyne range — I can expect to print reasonably well on a substrate with a surface energy in the 35–45 dyne level range. As an example, untreated PET is typically in the 30–32 dyne range, so I wouldn't expect to get good results from these inks without doing something to treat the substrate. One method is corona or flame treatment. Exposure to high voltage corona oxidizes the surface of the material, which increases the surface energy. Flame- or corona-treated PET is typically in the 37–38 dyne range, which would mean I am okay if my inks are in the 25–30 dyne level range. However, if the inks are more in the 30–35 dyne level range, I might need to consider chromic acid treatment, which will raise the dyne level to 39–40.

Other surface preparation methods are to clean with a solvent, such as Isopropyl Alcohol (IPA) and even a light abrasion. The goal is to remove any surface contaminants that might be interfering with a good bond to improve the chance of the ink adhering properly. A good cleaning with an IPA can go a long way to removing plasticizers that may have migrated to the surface and can affect adhesion.

Another area to be mindful of is the curing of UV inks. Ink can appear to be dry, however, it continues to cure (which allows adhesion to improve) in the first 24 hours and can continue for up to 72 hours. If possible, delay finishing (trimming, routing or cutting) when working with materials that you know will be a challenge for the ink to adhere.

Profiling is also an area that can affect ink adhesion. Many "canned" profiles have higher ink levels than needed for good color reproduction. This additional ink load can affect ink curing, and therefore affect adhesion. Understanding how to create a profile with the correct ink levels will go a long way toward better adhesion.

Introducing Adhesion Promoters

For those substrates with which these outlined suggestions don't work, there are adhesion promoters that may be used. Typically, different adhesion promoters are used for different substrates, so check with your printer manufacturer to see what they would recommend. Once you have selected an adhesion promoter you use a lint-free cloth to wipe the promoter on the substrate (usually only where the print will be). Most promoters do not need to be dried before printing, but it is important to make sure that a thin, even coat has been applied. Printing immediately after applying the promoter is best, but some promoters will exhibit good adhesion after sitting for a short time.

Flexible PVCs use plasticizers — held together by electromotive forces and not chemically bound — which soften the resin. Over time, these plasticizers migrate to the surface and make it difficult for ink to adhere. Another concern is substrates that have been treated (think of flame or corona treatment for coroplast). The effect of this treatment wears off over time and either needs to be redone, or the substrate will need an additional primer for ink adhesion. Developing a best practice for managing substrates to include cleaning methods and regular dyne testing is critical for success in printing.

Applying the Test

For hard-to-print substrates, Ridge shared his suggested test method. Start by cleaning half of the surface with IPA. Next, measure the surface tension across the entire substrate (using either a dyne pen or a dyne liquid set with a cotton swab applicator). Treat the surface — this could either be with an adhesion promoter, flame/corona treatment, etc. Print on the substrate and allow time for post-curing. As a last step, test for adhesion.

There is an "accepted" adhesion testing method known as the ASTM D3359-09 Cross Hatch and Tape Test, which outlines a method for making consistent cuts into the ink and prescribes the tape to be used. This is a borrowed test as it is used primarily for testing coatings to metals, but if you want a consistent and generally accepted testing method, this is a way to go. Alternatively, you should have a consistent method that you agree on and use at your shop that will let you know that you have acceptable adhesion when using your inks.

Don't forget finishing. Does the material need to be cut or routed? If so, test on a small piece using all the previously described techniques. Once you have printed and allowed to cure, try to cut the image. Does it chip when you work with it? If so, you may consider cutting the image first, and then overprinting. This can make the job inefficient, but if you have had difficulty getting the adhesion that you need to withstand cutting/routing, it may be your only option. Lastly, there are different blades and techniques you may also consider.

Please note that this article has focused primarily on UV inks as they are the inks that will be used in almost all flatbed printing, which is of course the prevalent printing method for printing on rigid substrates. With the expert tips and techniques that have been shared, you can establish best practices for receiving materials, testing substrates and remediation — if needed — which will enable you to deliver great quality time after time.

Ray Weiss, Director of Digital Print Programs for SGIA, joined the association in 2014. He provides solutions and technical information on digital printing as well as digital equipment, materials and vendor referrals. He oversees several workshops at SGIA along with the association's digital equipment evaluation program. Ray is the Project Manager for both the PDAA Certification program and SGIA's Digital Color Professional certification program and is an instructor for the Color Management Boot Camps. Ray is a regular contributor to the association's Journal and won the 2016 Swormstedt Award for Best in Class writing in the Digital Printing category. His 25+ year career in the graphics industry has spanned owning his own prepress and offset business to digital wide-format sales, training, support and service. Ray has extensive experience in color management and worked closely with the Smithsonian Institution to implement a color managed workflow in their Exhibits department.