The chemistry and art of screen printing

The art of screen printing is a long and fascinating history that intertwines molecular chemistry and visual creativity. The use of screen printing dates back to ancient China during the Song dynasty (960 to 1279 AD), but is more widely recognized for its commercial and artistic use in the 20th century, especially during the 1960s, the peak of the pop art movement. Screen printing is a fascinating and beautiful art, but how does it work and why is chemistry so crucial in its creation?

The early years of screen printing

The first screen prints created in ancient China had little to no new chemistry involved, but laid the basis for the techniques used centuries later. The process is simple and was used to transfer intricate designs onto fabrics efficiently by using stencils. Similar to silk screens today, there were two components to the stencil. First was the screen, a wooden frame with a sheet of mesh tightly stretched across it. The original mesh screens were made of human and animal hair, but was later changed to thin silk when the Japanese adopted the technique.

To create a design, stencils made from leaves or paper were placed on top of the screen to block out areas where ink wasn't wanted. The screen was placed on top of the fabric, and ink was applied on top of the mesh. The holes of the screen would act like pixels, with the ink seeping through the mesh in the desired areas, creating an accurate, and easily replicable image. Below: one of the earliest Song Dynasty screen prints

Screen printing's arrival in Europe

It wasn't until its spread in Europe in the 18th century did screen printing begin to take a commercial approach. The technique initially arrived through Chinese merchants in the 17th century trading along the silk road, and was adopted in France to create decorative fabrics and wallpaper. During its initial arrival, only stiff brushes were used to push the ink through a non-silk screen and its potential was largely overlooked. By the time screen printing became widespread, lithography was gaining tremendous popularity during the emergence of commercial art and Art Nouveau in France. Artists Alphonse Mucha, Henri de Toulouse-Lautrec, and Jules Chéret created some of the first mass produced advertising posters. Below: a lithographed beer advertisement by Alphonse Mucha created in 1897.

The chemistry of lithography

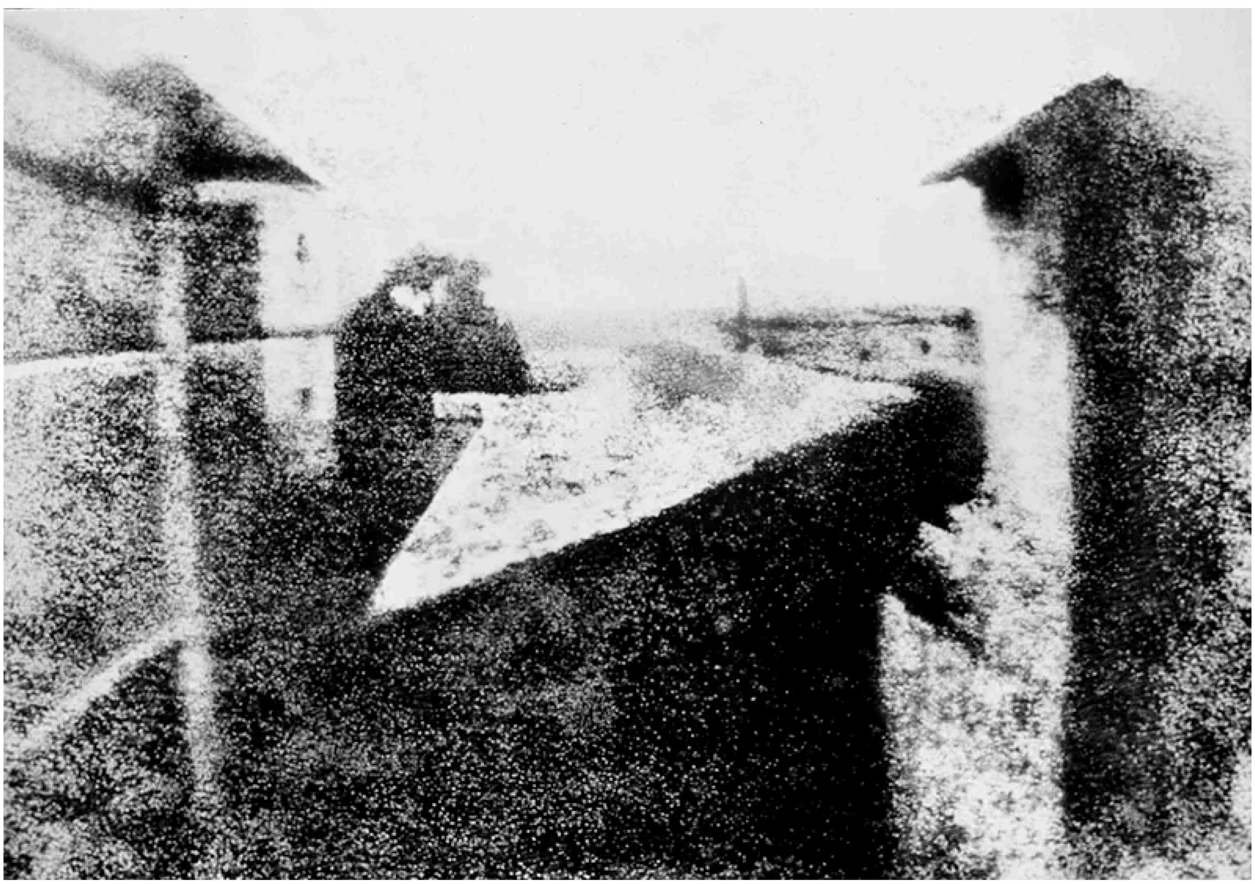
Before photography and modern screen printing, there was no practical way to efficiently reproduce art until the creation of lithography in the late 18th century. The principle of the process was created by Aloys Senefeleder in Germany in 1798. Lithography relies on the concept of repulsion between oils and water. The artist draws a picture with a greasy substance on a flat surface, typically limestone. The image was then chemically treated to make the grease attract ink and repel water, while the non-image areas attracted water and repelled ink. The chemical interaction between the greasy image and the wet, bare, stone enabled the reproduction of images in great detail.

The process starts with a smooth limestone slab, traditionally bavarian Limestone, popular due to its high concentration of calcium carbonate in the slab. To make the stone both hydrophilic (water attracting) and open to grease, the slab is ground with fine abrasives. This makes the stone just rough enough to absorb the water and oils, but smooth enough that the print will remain detailed and clear. The common abrasives used in lithography are levigated limestone or gum arabic solutions. After the stone is treated, the artist uses a greasy medium, lithographic crayons or tusche, to draw the image. After the oily substance adheres to the stone, the image areas now repel water.

After the drawing is completed, the stone is ready to be treated a second time to ensure the image areas stay hydrophobic. This treatment called etching usually involves applying a mixture of gum arabic and nitric acid to the entire surface of the stone. The gum arabic makes the surface of the stone not covered by grease more hydrophilic. It contains hydrophilic hydroxyl (-OH) groups, which are attracted to water molecules, making the gum-water coating that is applied to the stone retain moisture. The nitric acid added in the etching solution serves as the etchant, reacting with the limestone not protected by the grease. The nitric acid reacts and breaks down the calcium carbonate in the limestone, roughening the surface with microscopic valleys and irregularities that increases the surface area of the stone, providing more sites for the ink and water to adhere to. After the etching is complete, the grease pencil is wiped off. Although this seems counterintuitive, it does not remove the grease attracting areas of the stone. Removing the markings only wipes off excess ink that did not properly adhere to the printing surface. The necessary amount of grease is still invisibly embedded into the stone. Once the preparation of the stone is complete, the printer applies water to the stone which sticks only to the non-image areas, and oil based ink that only sticks to the greasy image, creating a detailed print.

The emergence of photography and its influence on screen printing

Prior to the early 19th century, there was no effective way to transfer a realistic image to paper besides painting. In the late 18th century, British scientists Thomas Wedgewood and Sir Humphry Davy were able to produce images using light sensitive silver nitrate and chloride, but these images were impermanent and quickly disappeared when taken out of a darkroom. The first successful photograph was produced in 1816 by Joseph Niépce using a camera obscura to expose a pewter plate coated with bitumen, a type of naturally occurring asphalt, to light. Taking eight hours to expose, this photo, unlike Wedgewood and Davy's, was permanent, and still remains as the oldest surviving photograph. Below: Niépce's first successful photo, showing buildings surrounding his estate in the countryside.



In 1839, Niépce partnered with Louis Daguerre, and were able to transfer Niépce's methods into the first photographic plates. The development of these plates greatly reduced exposure time from 8 hours to 30 minutes. Daguerre also discovered that images from these new photo plates could be made permanent by immersing them in salt after exposure. This revolutionary photographic method became known as the daguerreotype, and by the 1840s exposure times were reduced to under a minute, making them popular for common use.

In 1854, the cheaper, faster, and more reproducible carte de visite was patented by French photographer André Adolphe Eugène Disdéri. Disdéri, following the footsteps of an unidentified experimenter, covered his photographic paper with albumen (egg whites) to give the photo surface a sheen, preventing the exposed picture from sinking into the paper or plate, becoming fuzzy. After the introduction of the carte de visite, the popularity of the daguerreotype declined.

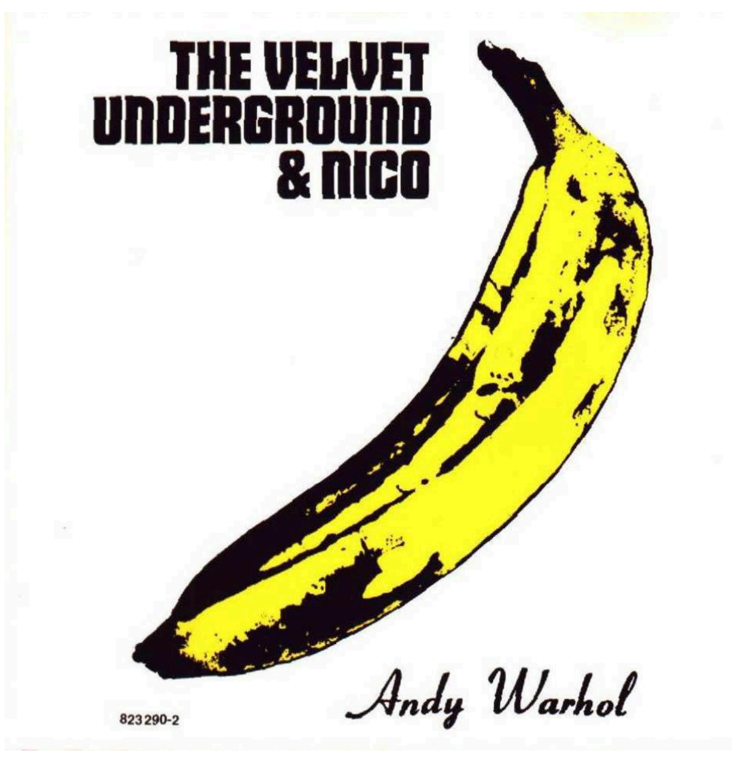
Two years later, English chemist and physicist Michael Faraday discovered and produced the first metallic colloid with gold. This development led to the use of colloidal silver halides in dry plates. Silver halide, similar to Humphry and Davy's silver nitrate, reacted when introduced to light, but did not fade after processing. Suspended in a gelatin binder, the metallic silver colloid could be applied to photographic paper. Below: The famous Lunch Atop a Skyscraper photograph taken in 1932 is an example of a photograph taken with a metallic colloidal plate. Generally attributed to photographer Charles C. Ebbets, and used as a publicity stunt to promote the construction of skyscrapers, the photo shows eleven ironworkers taking a lunch break during the construction of the RCA Building in Manhattan.

The silver halide format would remain popular up to the 20th century, and the method could be applied to silk screens. A thick photographic emulsion similar to silver halide could be coated to screens and a transparent film negative put on top after the emulsion dried. When exposed to light, places not covered by the dark areas of the negative would harden. When the screen is washed out, the light areas will stay attached to the screen while the still soft and underexposed dark areas would wash off in the water, making a photorealistic stencil.

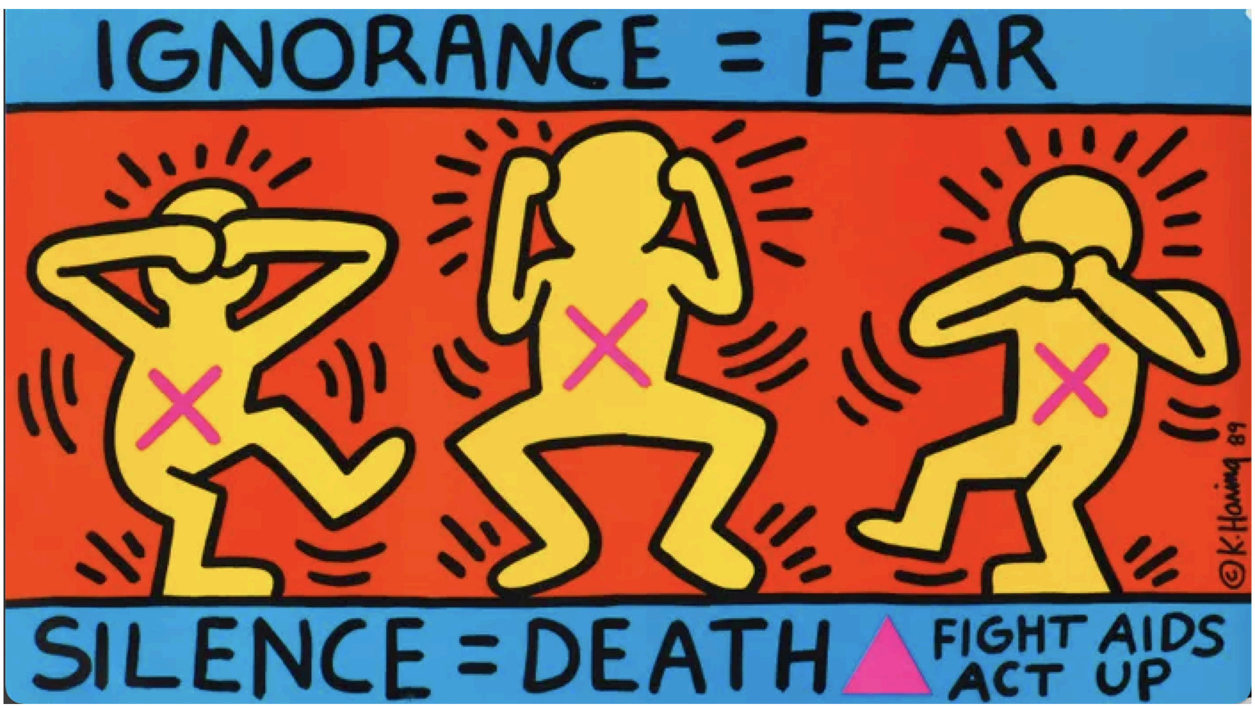
Screen printing in the 20th century

The transition between lithography and screen printing as the dominant commercial art form in Europe occurred gradually over time. Screen printing gained dominance in the early 20th century as a cost effective and versatile technique. The first modern screen printing system was patented in England 1907 by Samuel Simon, using bolting cloth stencils stretched across a wooden frame, a technique similar to what is used today. Advancements made in photography were also applied to screen printing techniques and silver halide became a useful tool for creating photo-imaged stencils for printing, which were introduced in the early 1910s.

The popularity of screen printing grew even more dramatically during the Great Depression as a result of the US government's Works Projects Administration (WPA). As part of Franklin Roosevelt's New Deal programs, new government run printing plants adopted screen printing to produce over 300,000 posters over an 18 month period, and government contracts were given to thousands of artists across the country to create prints for propaganda and advertising government programs. Below: Andy Warhol's iconic peelable screen printed banana featured on The Velvet Underground's debut album cover.



After World War II, screen printing's acclaim as an art form again decreased, being mostly used for the occasional advertising poster in the 50s. However, its popularity reached an all time high a decade later. The creation of the rotary multicolored screen printing press by Michael Vasilantone revolutionized the garment industry, leading to a boom in mass printed apparel. The heated political climate of the 60's led to a widespread use of screen printing to create bold graphics for political posters and protest signs. The affordability and easy access to screen printing materials as well as the "unprofessional" style of screen printed designs became a significant cultural aesthetic of the 60s, appearing on record covers, flyers, and other forms of media during the period. It soon became a staple of the Pop Art movement, being popularized by Andy Warhol. Both screen printing and lithography remained popular mediums for printmaking up to the 80s, but eventually fell out of style after digital printing methods were introduced in 1989. Below: Keith Haring's AIDS awareness poster produced on behalf of New York based AIDS activist group ACT UP. Created in 1989, this is one of the last instances of a mass produced lithographed poster.

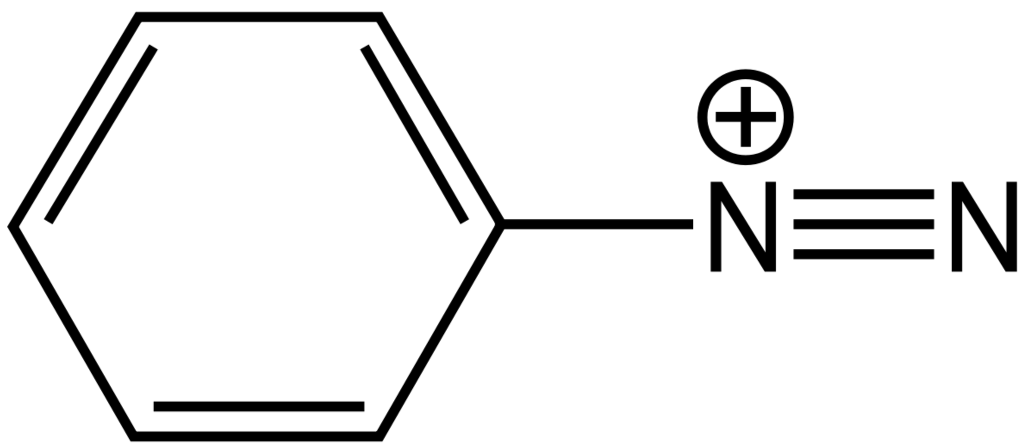


The chemistry of screen printing

The chemistry of screen printing is a similar, but less complex version of photography evolving the interaction of photosensitive compounds with light.
To create a photosensitive screen, a printmaker first needs to apply photographic emulsion. There are key differences in the chemical makeup of emulsions for photography and screen printing, as they fulfill different purposes.

The making of emulsion for photography involves adding a solution of silver nitrate into warm gelatin containing potassium bromide, sodium chloride, or other alkali metal halides. When mixed, the reaction precipitates fine crystals of insoluble silver halides, which become the light sensitive component of the emulsion that creates images in paper when exposed to light.

Screen printing emulsions, on the other hand, are not used to create images on paper. Instead of creating dark or light areas according to light exposure, the emulsion must create soft and hard areas. Since silver halides do not harden according to light exposure, diazo salts are used to make the emulsion photosensitive. Diazo salts are typically derived from the compound diazonium, composed of two nitrogen atoms bonded together with a positive charge and an aromatic ring, composed of a group of carbon atoms in a cyclic structure. These diazo salts, similar to silver halide, are light sensitive, but only when mixed with a polymer. Below: Diazonium's composition.



Diazo is typically mixed with polyvinyl alcohol (PVA) and polyvinyl acetate (PVAC). When exposed to UV rays, the diazo undergoes a photochemical reaction, crosslinking the polymers into a solid, insoluble stencil. However, the areas that remain underexposed have not undergone this reaction and remain in a soluble, liquid form. When the screen is washed off with water, the uncoupled polymers dissolve, while the rest stays hardened onto the screen. Hence, the ink is able to push through the blank areas where the excess emulsion dissolved, but not in solid areas where the emulsion hardened. Below: An example of one of Andy Warhol's screens, which were produced using photo emulsion.

To see his process in action, a documentary clip of Warhol printing a photograph of Marlon Brando: https://www.youtube.com/watch?app=desktop&v=CzrPmfaYcMM

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