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Further Developments of Film Emulsions

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ABSTRACT

The aerial imaging process has experienced many changes over the last decade due to the introduction of scanning of film, softcopy photogrammetry, digital workflow and the evolution of digital imaging sensors. Through all of these evolutionary changes, analog film remains a viable, and in many cases, a most desirable choice for data capture. The adaptability of silver halide films has enabled a 160-year-old technology to continue as a viable choice for data capture. This paper gives an overview of the competitive demands from the imaging market placed on film technology in recent years and the changes in film emulsion technology that has allowed it to adapt to these market needs. The paper will cover a short review of prior applications of film, present changes in the production process, technology applied to film emulsions thereby aligning the characteristics of film to better link to the present workflow technology. The paper concludes with a projection of film for years to come.

1. PAST FILM TECHNOLOGY AND APPLICATION

Since the first days of the discovery that silver salts were sensitive to light, and chemistry could be applied to preserve the image captured, it was not long before these early versions of sensitized materials were taken aloft on kites, balloons, and aircraft to capture images seen from above. A significant point of fact is that many of these early glass images still exist today and can be printed or scanned to reproduce copies on modern day materials. Emulsion technology has certainly evolved, but the basic technology of silver salt's sensitivity to light, converted through chemistry and copied via contacting or enlarging has not changed. What have evolved are the emulsion manufacture, the coating process, the film base material, processing chemistry, and all the ingredients in creating the original negative or positive image.

Black and white aerial imagery done up to about 5 years ago, lived within an analog production process. Film was exposed with an aerial camera, processed to a 1.3 average gradient, and copied to diapostives using CRT exposing equipment. The workflow then proceeded to analytical stereoplotting or mosaicing. Film emulsions were thick with high silver content to enable high process gammas.

Color negative film in the past was not as popular as black and white since the resolution and sharpness was less than black and white films, color was not pure or accurate, and the films were relatively slow in speed. The generation of a copy film, showing the natural colors virtually doubled the cost for both production and for the purchaser of the images. The best color imagery was attained using a color chrome reversal film but of course production then used the original image and in many cases this was not a desirable thing to do since the original could be damaged.

This was an environment where the human eye was the judge of a good or bad negative. Negative contrast and sharpness were the criteria for judging a negative. Poor negatives had some chance of being saved through the process of dodging in the CRT printer. Production could be maintained through the talents of good technicians in the stereoplotting departments. Films were required to have great flexibility in order for them to be able to produce some image on the film. The high silver content and thick emulsions allowed for variation in exposure and processing, even if the resultant quality was not optimal. New technology arriving in the market began to change the requirements for aerial imaging.

With the rapid development of digital scanning, a new method evolved for transferring an analog aerial image from film to softcopy. Additional improvements in digital image computing also progressed that allowed for the management of the large files produced through digital scanning of aerial images. With the progress made in digital equipment, demand was placed on the creation of software to capitalize on the progress made in computers and scanners.
Improvements in computer technology also allowed improvements in other manufacturing areas. One of these was in the manufacture of aerial cameras and optical systems. For years the basic aerial camera was a photomechanical device. Lens technology had evolved from designs many years old and aerial imaging was subject to limitations that included slow lens speed of 5.6 and edge sharpness fall off. The new computer technology allowed camera lenses to be redesigned to optimize resolution at fast apertures, better coating allowed for improved sharpness and contrast, electronics allowed for improved camera control systems. Additional improvements took place including gyro stabilized mounting, forward motion compensation, linking to on board computers for improved flight line accuracy and GPS.

Technology, hardware and software were not the only areas changing however. People were changing also due to influences brought about by movies, videos, television, globalization, the internet, personal computing and communications. These influences began to place a new demand on the type of imagery the "end users" were looking for in the delivered product produced by aerial imaging / photogrammetry companies. The next generation of employees and customers grew up in a very visually stimulating environment with sophisticated graphics, brilliant color, instant copies and fast communication. This market does not tolerate poor black and white images, inaccurate color, long production times. Demand for high quality photo images with realistic color, improvements in cameras, lenses, and the introduction of scanning set the stage for improvements in film emulsion technology.

2. NEW FILM TECHNOLOGY

Science has not abandoned film technology. What has taken place in film and film emulsion technology has been rather quiet but no less revolutionary.

The substrate or the base material on which the emulsion is coated has had many changes. Agfa makes its own polyester base material and this allows for its own technology to be applied. Polyester is used for aerial film for the dimensional stability and strength needed in aerial imaging applications. Unique to Agfa's polyester is the incorporation of permanent anti-static properties that allows the film to remain anti-static both before and after processing of the film[11]. This is a very important function and a critical element when using the film in scanning applications. Film that is not permanently anti-static can loose its anti-static properties after processing. This will cause the film to attract dust and make the dust more difficult to be removed. Dust particles on a film negative can add considerable time to production in cleaning up the spots after scanning. Agfa's polyester is also filtered during the manufacture process to eliminate impurities larger than 10 microns in the base.

In the coating process, the base is of course coated with an emulsion on one side, but also coated on the back to insure flatness of the film during scanning production. The concept of back coating would be similar to painting only one side of a piece of thin plywood. As the paint dries the plywood curls. If you paint both sides of the plywood, it stays flat. The back coating of the film also acts as a protection against scratching of the back layer during film processing. Fine scratches in a film without a gelatin coated back layer show up very easily in scanning. Digitally retouching to remove scratches after scanning again contributes to time needed in cleaning up the image. To improve the vacuum characteristics, tiny grains of silicium are added to the back coating. These tiny grains maintain a microscopic space between the film and glass or a copy film insuring even evacuation of air during vacuum eliminating or reducing the possibility of Newton rings.

The move from using analog copying of films to scanning the original negative and softcopy required different emulsion characteristics in the original aerial data capture film. Scanners prefer images that are high in resolution and low in contrast[6]. This is very different from what was desired in the past. The human eye has a very low tolerance to un-sharp edges and requires sharpness and contrast for details to be determined[9]. The smaller the size of the object, the higher the contrast needed. A CCD scanner generates a signal equivalent to a linear light input. Low- density film image parts will create a very modulated and high output signal, as the scanner picks up the smallest density variations. For negative films, this means that the best discretion of information is being collected in the shadow aereas.With the scanner, resolution becomes more important than sharpness. A fine-grained, high-resolution film can deliver more information with less noise, maximizing the useful data conversion space available in the analog/digital conversion process.

Agfa film emulsions use a unique “structured twin crystal”[4,5]. A twin crystal consists of a core of silver iodide surrounded by a shell of silver bromide. This combination produces a much more sensitive silver halide crystal that is able to absorb more light than conventional crystals. This design of silver halide crystal is thinner allowing a higher volume of crystals to be put into a thinner emulsion layer without sacrificing sensitivity. This thinner emulsion produces less light scatter in the emulsion resulting in a sharper image. The structured twin crystal improves sharpness and grain relative to the film speed.

Not new to film emulsion manufacture but a technology that continues to change is a technique referred to as doctoring[10]. Dyes can be added to a black and white emulsion during the coating process that can add unique functionality to a film. Aerial films benefit from Agfa’s doctoring that provides an extended red sensitivity range to the near infrared, 750nm. All the Aviphot black and white films include this extended sensitivity[1]. Doctoring of the film emulsion is not just an option but a necessity since silver halide un-doctored is only sensitive to UV and the blue light spectrum in the 400nm range. The doctoring of film is unique to every manufacturer and is one of the reasons films from various manufacturers differ widely.

It is anticipated that aerial film will have advantages in large scale imagery for many years, where the combination of film resolution, good film speed coupled with the latest analog aerial cameras will be able to maximize ground details or “spatial resolution”. This spatial resolution can then be matched to the appropriate scan resolution[8]. Color film technology has experienced dramatic changes over the last decade and continues to evolve. Today, color negatives are regularly scanned at 12 microns. It was not long ago when no one would have considered scanning a color negative at less than 25 microns. The breakthrough technology came from another area, that of consumer imaging film and Advance Photo System technology or APS[4]. The need was for a film format smaller than 35mm capable of producing large size prints of high quality. This technology was quickly adapted to aerial film. Film speed was increased through the use of coating multi-layers of silver halide of varying grain size. In conjunction with a new development technology where inhibitors are released during development that reduce the size of the larger silver grains, the film speed is maximized while the granularity is minimized. Improvements in color were made through the use of interlayer effects taking place during development. These interlayer effects allow the transition of inhibitors to move between layers in the film emulsion resulting in enhancement of dominant colors and the elimination of unfiltered light producing impure colors[4]. Adaptability of film technology allowed for the orange mask to be eliminated resulting in Agfa Aviphot X100[2] clear based color negative film exclusively adapted to aerial imaging. This allowed for improved signal to noise ratio in scanning providing increased usable data. Along with the use of the latest color layer and development technology, there was very little loss in color fidelity and purity. However, the very best color capability lies with masked color negative films. As the market continues to push for brighter and purer colors, the masked film technology has an advantage. As the new generation of photogrammetric scanners emerges, there are less and less problems in scanning from a masked color negative film. The latest Agfa Aviphot HX100[3] masked color negative film can produce grain-less images at 10 microns.

3. FILM TECHNOLOGY WILL CONTINUE TO EVOLVE

Film emulsion technology is not finished and there is no reason to expect it would end. As digital technology continues to improve and change, so will the use of film. The adaptability of film will enable it to transition to various applications.

One area that film can change dramatically is in its film speed. The use of a process called "doping" can increase the speed of a silver halide film by 5 times[7]. In present emulsions as much as 10 photons of light is needed to produce a developable latent image. Using formate ion (HCO_2) as a "dopant", will allow only 2 photons to produce a developable latent image. This will enable the use of smaller crystals producing higher speed. The result will be a fine-grained, high resolution film 5 times faster than the highest resolution film available today. This doping can be applied to both black and white and color films resulting in dramatically new film emulsions than are presently available.

Films archival ability may allow it to find additional potential in the future. Writing files to film insures the files survival and the data can easily be retrieved using a scanner / film reader.

The market will determine where film will be used and how it will be used. As different imaging technologies come to the market, film will migrate to the area where its attributes will have the best advantage. The adaptability of film will continue to allow for optimization, thereby insuring its survival well into the future. Film is the benchmark by which all new imaging methods is measured. While the newest imaging technology is still evolving, aerial mapping companies will continue to rely on film technology to make money now. The excellent marriage of film to digital through scanning is a good one and continues to progress.

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5. REFERENCES

1. Agfa Aviphot Pan 80 PE1 Information document. Agfa Gevaert N.V. Mortsel Belgium 2001

2. Agfa Aviphot Color X100 Information document. Agfa Gevaert N.V. Mortsel Belgium 2001

3. Agfa Aviphot Color HX100 Information document, Agfa Gevaert N.V. Mortsel Belgium 2002

4. Technical Photographic Terms, Ulrich Skaer/Dieter Weis, Agfa Gevaert AG, Leverkusen, Germany 1998

5. Basic Information on Photography, Ulrich Skaer/Dieter Weis, Agfa Gevaert AG, Leverkusen, Germany 1996

6. From Light to Electrons, An Exploration of Digital Imaging Hardware, Agfa Gevaert N.V. Mortsel, Belgium 1999.

7. Photo Techniques, November 2001, pp 16 – 19, Photochemistry, Robert Chapman,

8. The Imaging Science Journal Vol 49, Spatial resolution implications of digitizing aerial photography for environmental applications, T. Nelson, M. Wulder, K.O. Niemann

9. Image Clarity, High-Resolution Photography, John B. Williams, Resolution and Human Vision pp 39-46

10. Van Nostrand's Scientific Encyclopedia 7th Edition, Consodine, Photography and Imaging pp 2200-2205

11. Press release October 12, 2000 Mortsel Belgium, Alan Heeger, Alan MacDiarmid, Hideki Shirakawa receives Nobel Prize 2000 for Chemistry. Applied technology of conductive polymers.