Advances In Low Speed Imaging: KODAK VISION2 50D Color Negative Film 5201 and KODAK VISION2 Color Negative Film 7201

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Abstract

EASTMAN EXR 50D Film 5245 and EASTMAN EXR 50D Film 7245 enjoyed a unique position in the portfolio of motion picture color negative films as the lowest speed daylight film, offering minimum granularity and relatively high contrast and acutance. Since the introduction of the EXR Film family sixteen years ago, a significant number of advances in silver halide-based imaging technology have occurred. The latest additions to the VISION2 Film family, KODAK VISION2 50D Color Negative Film 5201 and KODAK VISION2 50D Color Negative Film 7201, capitalize on these fundamental enhancements and are a testament to how improvements in core imaging technology translate into film performance. This talk will focus on the description of these technologies as well as data that compares the performance of 5201 Film with other camera origination films.

Imaging Efficiency Technologies

As silver halide film technologies continue to advance, one of the key areas targeted for improvement is that of imaging efficiency throughout the complete imaging chain, exploring and identifying technologies to improve the way in which photons are captured by the silver halide crystal and are ultimately converted into dye density. The desire is to be able to obtain the highest signal (resulting dye density and improved acutance) at the lowest noise level (reduced granularity). Several new technologies have been introduced with the Vision2 family of films that enable significant improvements in imaging efficiency. These advances are echoed in significant enhancements to the image structure of these films.

To quantify these performance improvements observed with the Vision2 films, it is necessary to first establish the relationship between the objective, conventionally measured elements of granularity, acutance, and sensitivity, to their subjective, user-dependent counterparts perceived as graininess, sharpness, and speed. A film's performance can be characterized by its microdensity fluctuations, or σ_D , its acutance as measured by the modulation transfer function or MTF, and by the minimum amount of exposure required to achieve a sensitometric response. The relationship between these parameters is key to understanding how effectively an imaging element will translate original scene information into the final captured image.

The imaging chain can be summarized in simple terms by the following sequence: incident photon capture, latent image formation, latent image identification, latent image amplification, and density formation. Each of these steps has its own mechanisms, some of which can either improve or degrade the efficiency of the chain. Detective Quantum Efficiency (DQE) as described by Jones [1] has been broadly used to summarize the overall imaging efficiency. In simple terms, DQE is a measure of signal to noise (S/N), a ratio between output to input information. Each of the steps in the image capture chain contributes to DQE by means of a rule of products and, thus, an improvement in the efficiency of any particular step will lead to an improved overall DQE. In other words, improvements made at any level of the chain will result in an improvement in overall photographic performance.

As it relates to a photographic system, DQE can in a simplified sense be viewed as the volume contained within the solid object defined by its sensitivity, gamma acutance, and granularity. Enhancing the sensitivity, gamma, or acutance will result in an increase in efficiency, while an increase in granularity will result in degradation of the system performance.

Sensitivity, acutance, and granularity are related in such a way that an improvement in any of them would lead to a degradation in the other. For example, an increase in sensitivity generally comes at the expense of higher granularity. Multiple mechanisms exist that trade one feature for another, however, unless there is a fundamental improvement in the efficiency of the imaging process, the signal to noise remains fairly constant.

In regards to incident photon capture, tabular grain emulsions play a key role in this step of the imaging chain. Generic to the Vision2 platform is the use of these high aspect ratio structures that maximize surface area per unit volume and thus enhance the utilization of light while providing for the opportunity for reduced crystal mass, reduced surface area per crystal, and increased number of centers (reduced granularity by way of the random dot model) while achieving the same sensitivity as the larger emulsions used in 5245. Table 1 shows some examples of the surface area reduction achieved by implementation of this technology into Vision2 5201.

Table 1. Relative Emulsion Volume of most light sensitive emulsion by color record.

	5245 (μ^2/grain)	5201 (μ^2/grain)	Percent Area Reduction (μ^2/grain)
Fast Yellow	1.58	1.48	7.0
Fast Magenta	1.21	0.76	59.0
Fast Cyan	2.21	1.42	56.0

For the latent image amplification stage, Kodak Vision2 50D film incorporates the use of molecules known as advanced development accelerators [2]. This compound improves the probability that the developer molecules will identify latent image centers when these react with exposed silver halide during the amplification phase. Figure 1 is a graphical representation of the granularity improvements achieved by the integration of the technologies previously discussed.

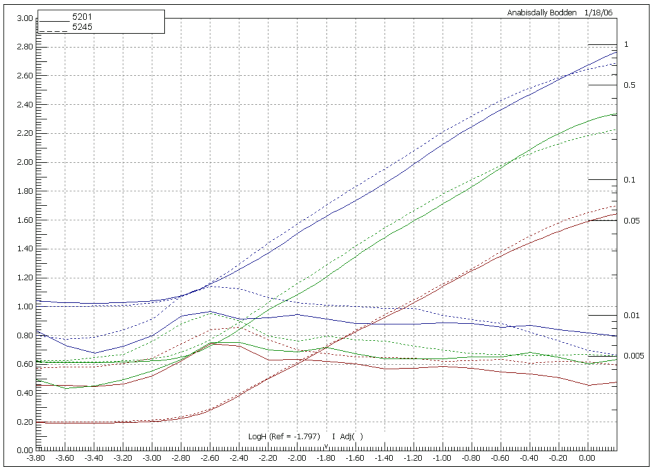

***Figure 1**. Vision2 granularity profile.*

The emulsions used in Vision2 50D have been designed to provide higher efficiency by optimizing the iodide structure and dopant levels in ways that prevent destructive recombination events that limit the number of electrons available for latent image formation. As a result of the use of Vision2 50D as a recorder output film, the level and selection of a combination of inorganic and organometallic dopants in these tabular grain emulsions were also optimized. They provide sensitometric performance that is more robust to the product of intensity and length of exposure. In other words, the effect of reciprocity failures inherent to silver halide crystals is greatly mitigated with the introduction of these emulsions (see Figure 2).

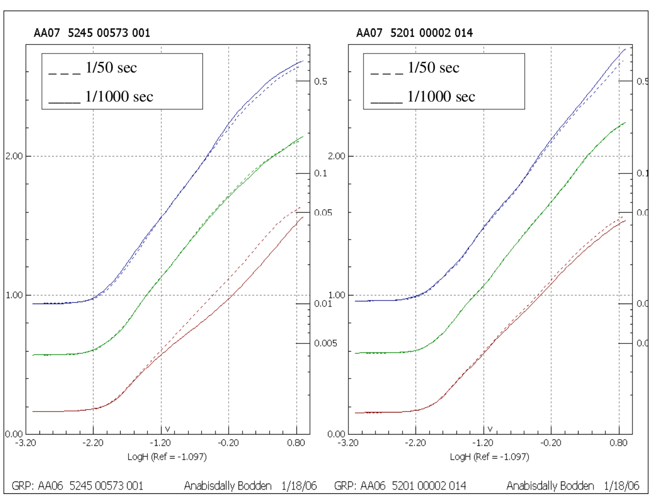

***Figure 2**. High intensity reciprocity of Vision2 50D vs 5245.*

Sensor Segregation Technology

In addition to the core chemical technologies introduced in Vision2 50D, a strong emphasis was also placed on film architecture strategies in order to update this film up to platform standards for photographic qualities other than image structure. Color reproduction and tone scale linearity are two attributes to consider.

Regardless of the low noise or sharp image that is produced, if the color reproduction is not managed properly, the resulting image will be unusable.

The first of the strategies is sensor segregation. Ideally, the best way to control color and tone scale reproduction through the exposure scale is to have sensors that are activated exclusively in the area of the D log E curve where they perform optimally (lowest S/N) and immediately after they are deactivated. The chemical nature of the film system does not easily allow for this instantaneous on/off behavior from the chemistry that is used. In general, there are at least three components (fast, mid, and slow sensors) used in each of the color records to achieve the sensitometric response from underexposure all the way through to overexposure. In order to truncate the contribution of the larger components (larger crystal, higher granularity) throughout the scale, the color records are subdivided. In 5245 all three records are subdivided into two subrecords, a fast and a slow layer. This allows for an increased number of degrees of freedom when managing and controlling the noise, tone scale, and color contribution of the different size emulsions to the overall response of the film. For Vision2 50D this concept has been extended to the subdivision of the cyan and magenta records one step further. These two records are now triple-coated (fast, mid, and slow layers), thus, increasing even more the flexibility for tone, color, and noise reproduction control (see Figure 3).

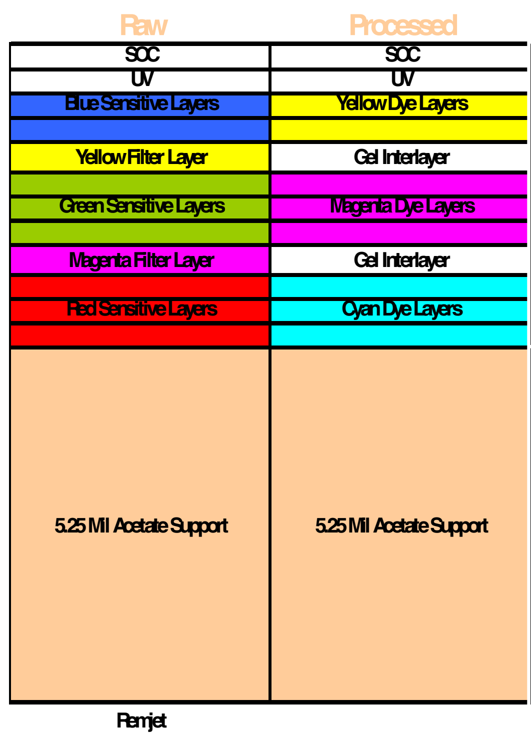

***Figure 3**. Vision2 film structure.*

The B/G and G/R interlayers of 5201 have also been optimized to improve the ability to separate the three color records from each other both spectrally as well as chemically. Introducing a compound in the interlayer that intercepts the oxidized developer generated in one specific color record, for example the green, such that it cannot form colored dye in the blue or red record, minimizes chemical “crosstalk.” The spectral separation, on the other hand, is achieved by the use of solid particle filter dyes (yellow and magenta), which capture any residual blue or green light before it hits the underlying green or red record, respectively. As a result, green colors have less blue in them and red colors have less green, a more pleasing and cleaner color reproduction (see Figure 4). The combination of improving both the spectral and chemical integrity of the underlying green and red records, while avoiding signal loss caused by development artifacts, contributes to an overall net gain in imaging efficiency, relative to the more conventional methods of managing the native blue sensitivity of all silver halide sensors.

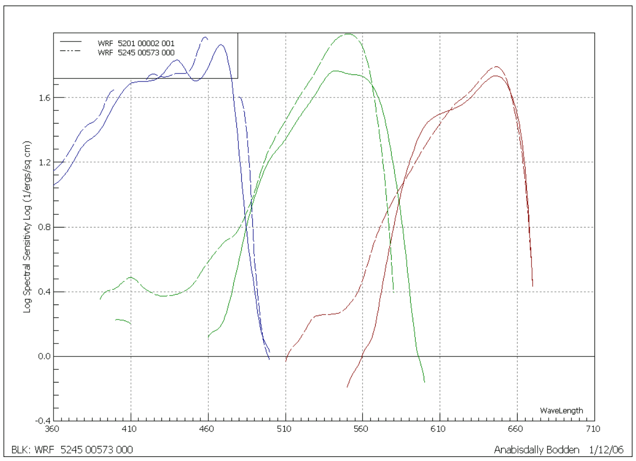

***Figure 4**. Vision2 50D spectral sensitivity vs 5245.*

Additional Film Features

Following the platform standards of the Vision2 family, one of the key features provided by 5201 is tonescale linearity. Figure 5 summarizes the linearity of the Vision2 50D vs EXR 5245 50D, complete with first derivative curves to relay point slope characteristics. In 5201, the midscale linearity has been greatly improved, as well as has the overall latitude of the film. Throughout the exposure scale, the three color records are aligned to maintain neutrality. The lower portions of the curves (toe, representing the darkest area in the image) are better matched to one another vs 5245; this results in improved shadow neutrality. The lower contrast, “softer” toe translates into a more natural reproduction of shadow detail as well as an increase in underexposure latitude. Also note that 5201 has a lower overall contrast than 5245. This enables 5201 to be more compatible with current intermediate and print film systems. In concert with the color reproduction characteristics of 5201, this lower contrast position also allows for seamless intercutability of this film stock with other Vision2 codes.

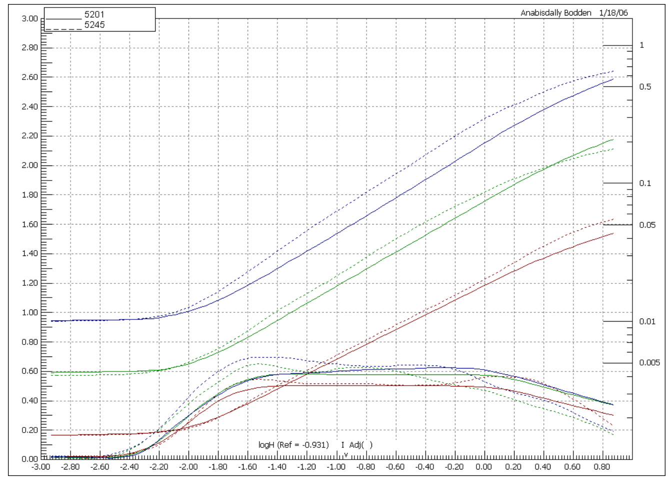

***Figure 5**. Vision2 50D tone scale vs 5245.*

An additional feature brought forth in the design of Vision2 50D is a significant improvement in red channel acutance. This was identified as a shortfall of 5245 specifically when it came to recorder output applications. The combination and optimization of silver halide and DIR technologies were utilized to make this improvement possible. Figure 6 shows the normal MTF response of the red record and compares it to 5245.

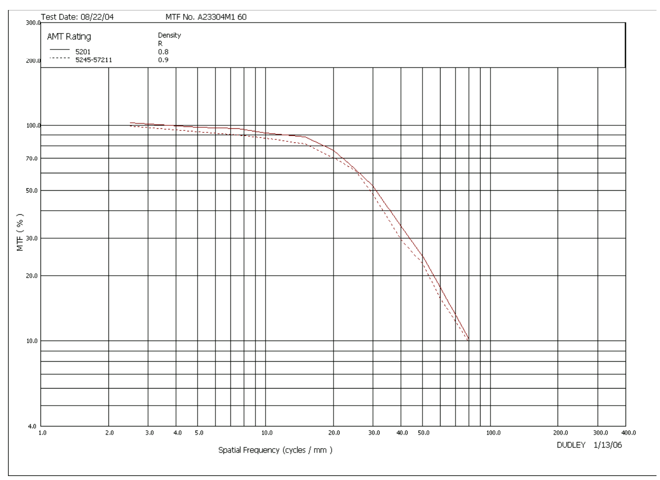

***Figure 6**. Vision2 50D MTF Plot vs 5245.*

Vision2 50D is the latest addition to the Vision2 family of films. The quality improvements evident in this film are a true testament to what advances in silver halide technology can deliver. Whether the images are printed or scanned for digital use, the benefits of this film stock are clearly perceptible.

References

[1] T.H. James, Editor, “The Theory of the Photographic Process,” 4th ed., (MacMillan, New York, 1977).

[2] Philip Allway, Bernard Clark, John Goddard, Louis Friedrich, James Friday, Stephen Singer, and Marcello Vitale, “Color photographic element containing speed improving compound,” US Patent 6,319,660, 2001

[3] David Long, Michael Ryan, and Roger Morton, “Kodak Vision2 500T Color Negative Film: A Digital Film for the Digital Future”. SMPTE Motion Imaging Journal, Oct-Nov 2004, pg. 348.

Author Biography

Anabisdally Bodden received her B.S. in Chemical Engineering from the University of Puerto Rico in Mayaguez and her M.S. degree in Mathematics and Applied Statistics from the Rochester Institute of Technology. Since 1997 she has worked in Research & Development at Eastman Kodak Company in Rochester, NY. Her work has concentrated in the design and research of motion picture films.