A High Speed Color Reversal Film with High Color Saturation and Image Qualities "Fujichrome PROVIA 400X"

Fumitaka Ueda, Masatoshi Goto, Shigeru Kuwashima, Kimiyasu Morimura,Nobuyuki Haraguchi, Masayoshi Toyoda, Hiroshi Fukuzawa and Hideo Ikeda

Material Research Division, Fuji Photo Film Co., Ltd.210 Nakanuma, Minami Ashigara, Kanagawa, 250-0193 Japan

Abstract

Fujichrome PROVIA 400X, which was released in February 2006 by Fuji Photo Film Co., Ltd. is the highest in image-structural qualities and color saturation as well as long-term image stability among ISO 400 color reversal films . These new features have been realized by the following state-of-the-art innovative technologies ; Epitaxial Sigma Crystal technology , Pure , Stable & High-performance dye-forming Coupler technology , and Multi-Color-Correction Layer technology.

Introduction

In February 2006, Fuji Photo Film launched a new high-speed color reversal film Fujichrome PROVIA 400X. Color reversal films have been enthusiastically used by a lot of professional and "advanced amateur" photographers owing to the fact that they are featured with high color saturation , "image color" reproduction, and natural tone reproduction . The granularity and color saturation of the new film are about the same as those of conventional ISO 100 speed films. In this paper, we report the recent progresses in color reversal films and describe the excellent features and technologies implemented in PROVIA 400X.

Photo 1. *Fujichrome PROVIA 400X.*

Significance of Improvements in High-Speed Color Reversal Films

Color reversal films are used by professional and "advanced amateur" photographers . Especially in Japanese market, color reversal films with high color saturation have been enthusiastically supported by them for taking pictures of nature (e.g., flowers and landscape) even after 2000 when digital still cameras came into wide use. This also indicates that the users highly appreciate color reversal films with minutely controlled tone reproduction over wide dynamic range from highlight to shadow, enhanced color saturation by interlayer effect, vivid color

reproduction by use of couplers forming dyes with pure colors, and high image-structural quality. In addition, color reversal films are reliable for those, who want to reserve their pictures as works of art. One of the reasons for the reliability is attributed to the fact that the original images are kept as they were in color reversal films on the contrary to DSCs, in which they are kept as numerical data. The other reason comes from the fact that the images are stored as those in ready-to-view state in color reversal films for quite a long time on the contrary to digital systems, in which it is not sure if stored image data will be accessible and eadable in the future owing to technological changes, which will take place rapidly in media format.

Films with sensitivity of ISO 400 or more hardly put us to such troubles as camera shake and action blur, and make it easy to take pictures under low illuminant conditions.

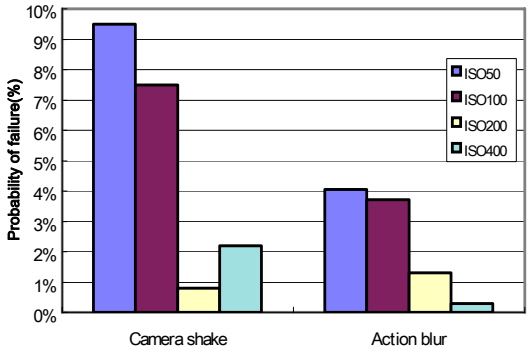

Figure 1. *Probability of failure by camera shake and action blur.*

The most typical examples of the characteristics are as follows: However, many users choose a slower color reversal film rather than a faster one. One of the reason for this preference comes from the fact that a faster color reversal film gives an image with lower color saturation and inevitably coarser granularity than a slower one .

It is therefore obvious that they want faster color reversal films with improved image qualities and high color saturation.

In order to meet the user's request, Fuji Film released ISO 400 color reversal film Fujichrome PROVIA 400X, which is so high in color saturation and so fine in granularity as to provide a

picture, whose image quality is nearly on a per with that of ISO 100 films.

Features of PROVIA 400X

In Fujichrome PROVIA 400X (RXP), we have improved its granularity as compared with its predecessor PROVIA 400F(RHP III), and achieved a high color saturation on the basis of the technologies, which was developed for previously released Fujichrome Velvia 100 et al.

1.Sensitivity and image-structural quality

We have significantly improved the graininess of PROVIA 400X by means of Epitaxial Sigma Crystal technology, which has made it possible to reduce the size of the silver halide grains in it without deteriorating its sensitivity. As shown in figure 2, the RMS granularity value of PROVIA 400X has been improved so greatly as to reach 11, which is the highest among ISO 400 color reversal films ever produced in the world and is approaching those of ISO 100 color reversal films.

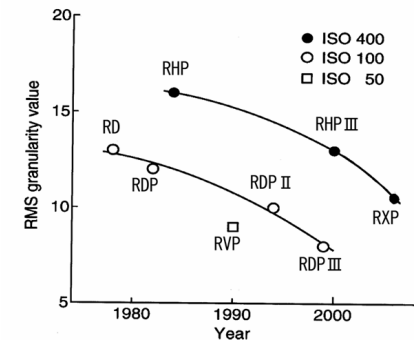

Figure 2. *Improvement in RMS granularity value of Fujichrome*

2.Color Reproduction

In order to improve color reproduction, we have applied to PROVIA 400X the Multi-Color-Correction Layers (MCCL) technology, which is our original technology with newly developed couplers for forming yellow, magenta, and cyan dyes and was introduced into Velvia100, Velvia100F, and ASTIA100F [2)].

Using these technologies, we have achieved the highest color saturation in PROVIA 400X among color reversal films with sensitivity of ISO200 or more.

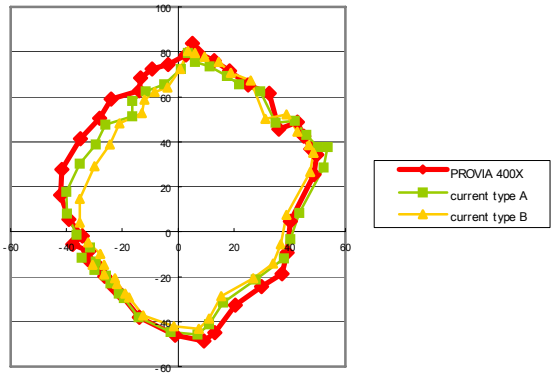

Figure 3. *Comparison of the color reproduction performances between PROVIA 400X and some currently used color reversal films.*

Fig.3 illustrates the comparison in color reproduction between PROVIA 400X and some currently used color reversal films in terms of CIE-Lab color space, where the distance from the center corresponds to the degree of color saturation.

In addition, we have achieved the smooth and beautiful reproducibility of flesh color by means of the MCCL technology, by which inter-layer effects are emphasized in bright highlight areas to increase the densities of magenta and yellow, and to decrease the density of cyan in flesh color.

Provia400X is unique in that it is suitable, not only for taking portraits owing to its outstanding reproducibility of flesh color, but also for taking landscape pictures owing to its high color saturation.

3.Image Stability

We have improved the dark storage image fading of PROVIA 400X by introducing the above-stated new couplers into it. It has been predicted from the Arrhenius plot of the data obtained under elevated temperature that the images formed in PROVIA 400X will be maintained with acceptable quality for 100 years under the condition at 25℃ and 70 % relative humidity, which is the average climate of Japan, as seen in Fig.4.

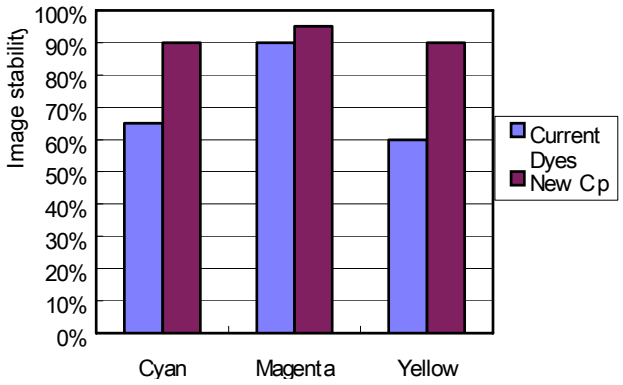

Figure 4. *Dye image stability of the new couplers.*

When the images will be preserved at 40% relative humidity, they will be more stable and maintained for a longer period of time than those kept under the above condition.

Moreover, the image stability of magenta dye under illumination, which was the most inferior among the dyes of three colors, has been improved and become to be about twice the stability in the predecessor by adopting the new magenta coupler.

Technologies developed for new films

1) Epitaxial Sigma Crystal (ESC) technology

We have achieved the graininess in PROVIA400X, which is as high as to be comparable to those in ISO100 reversal films, by means of the following ESC technology, which has made it possible to reduce the size of the emulsion grains without deteriorating their sensitivity.

1.Structure of ESC grain.

In order to improve image structure, it is necessary to enhance sensitivity without increasing the size of emulsion grains. For this purpose, we have considered that the enhancement of the light absorption of individual grains is promising. It is well known that the increase in the aspect ratio of a tabular grain brings about the

increase in its surface area, the amount of sensitizing dye adsorbed on it, and therefore the enhancement of its light absorption.

In ESC technology, we have enlarged the average aspect ratio of the tabular grains in PROVIA 400X up to about 18, which is much higher than that of the grains in the predecessor (i.e., about 4). Then, they have been used as the substrates for forming epitaxial microcrystals at their corners. (See Photo2).

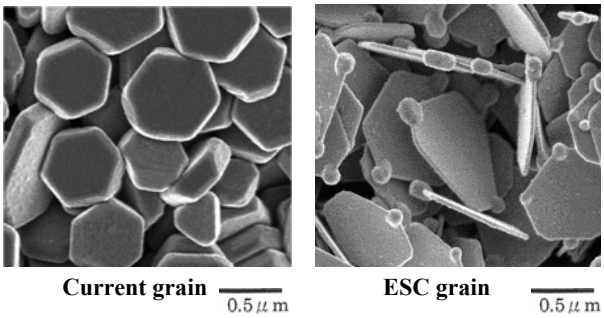

Photo2. *The comparison in shape between current and ESC grain.*

In order to enlarge the aspect ratio of the tabular grains, we have removed the condition with ═ the presence of highly concentrated iodide ions on the grains, which depresses the anisotropic growth of the grains. In order to prepare the well defined epitaxial microcrystals, we have used so-called site directors and controlled their adsorptivity to the grains and coverage of the grains. Site directors are actually sensitizing dyes and capable of enhancing the formation of the epitaxial microcrystals at the corners of the tabular grains.

Although epitaxial microcrystals on a silver halide grain usually contain a large amount of AgCl, we have removed AgCl from the epitaxial microcrystals on an ESC grain so as to resolve the problems in grain-stability such as the changes in grain-features during their manufacturing process, incubation, and processing. This treatment is based on the idea from thermodynamic viewpoint that a large gap in halide composition between a substrate and epitaxial microcrystals makes the grain unstable [1)].

2.Technologies to achieve enhanced photographic sensitivity

To enhance photographic sensitivity, we have adopted the tabular grains with high aspect ratio, which are suitable for capturing incident light effectively. The preparation of the grains with high aspect ratio has been realized by removing the process, which enhances the isotropic growth of the grains. Namely, the process, which introduces into the grains crystal defects originating from the discordance between different silver halide phases, brings about the formation of dislocations, which make it difficult for the tabular grains to grow anisotropically. On the other hand, it is known that dislocations play important roles in photographic process, acting as transient electron traps, which thus prevent the trapped electrons from recombining with positive holes, and enhancing the formation of sensitization centers by providing the sites suitable for it. Alternately, the epitaxial structure of our new grains provides various functions including those caused by dislocations.

While the surfaces of tabular grains in PROVIA 400X are covered with a large amount of sensitizing dyes, the epitaxial microcrystals on the grains are practically free from the dyes capable of capturing positive holes, being preferable sites for the formation of sensitization centers and also latent image centers. Thus, the epitaxial structure prevents electrons and dye positive holes from encountering and recombining with each other, resulting in the improvement of the efficiency of latent image formation. (Fig.5).

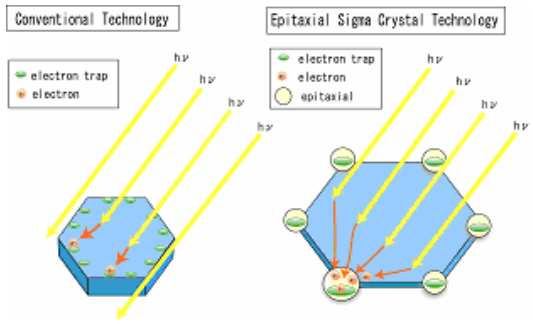

Figure 5. *The improvement of the efficiency of latent image formation.*

The observation of the grains at the early stage of their development process by SEM has revealed that silver specks originating from latent image centers are growing at the interfaces between the host and epitaxial parts of our new grain (PHOTO.3).

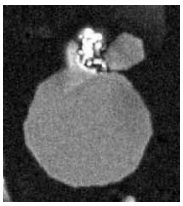

Photo3.

3. Technologies to reduce color stain

It is predicted that color stain caused by residual sensitizing dyes becomes worse as the aspect ratio of the grains increases. In addition, it has been found that oily droplets such as couplers keep some sensitizing dyes by dissolving them and deteriorate the color stain. In order to resolve this problem, we have developed the new emulsifying surface active agent to prevent oily droplets from dissolving sensitizing dyes. This technology has achieved by about 25% the reduction of the color stain in PROVIA 400X as compared with its predecessor.

2)Pure Stable & High-performance dye-forming Coupler (PSHC) technologies

The imaging dyes, which have been induced by the newly developed yellow, magenta, and cyan couplers for PROVIA 400X have excellent spectral characteristics with little unwanted spectral absorption. Therefore, they have brought about the expanded reproductive color gamut and enhanced color saturation in PROVIA 400X.

We consider that the structures of the imaging dyes are rigid enough to give such excellent spectral characteristics with little unwanted spectral absorption.

In addition, these new couplers have merits to form the imaging dyes with enhanced stability in the dark storage. Especially,the image stabilities of the yellow and cyan dyes were inferior to that of the magenta dyes in the predecessor color reversal film. Using the newly developed couplers, we have successfully improved the dark storage stabilities of the imaging dyes for all the three colors.

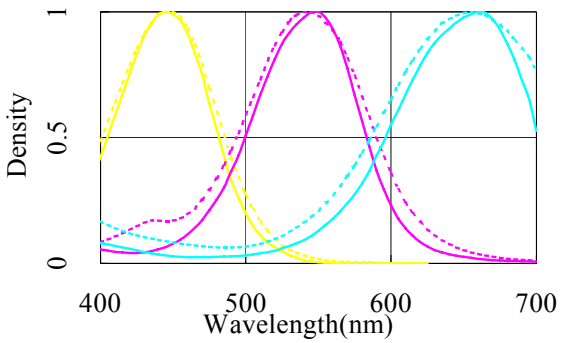

Figure 6. *Spectral Characteristics of the dyes induced by the new couplers.*

3) Multi-Color-Correction Layers technology

In PROVIA 400X, we have introduced the fourth color layer (i.e., green color correction layer),the fifth color layer (i.e., blue color correction layer), and the sixth color layer (i.e., red color correction layer), which emphasize interlayer effects without directly contributing to image formation. Each color correction layer is not used to form any dye image by itself and is used to improve color saturation by causing such an interlayer effect as to inhibit the development in the other image forming layer, at which the interlayer effect is aimed. We have realized high color saturation and excellent fresh tone reproduction by the interlayer effects, which are emphasized in bright highlight areas owing to the effects of the color correction layer technology [3)].

Conclusion

Fujichrome PROVIA 400X is the epoch-making color reversal films , achieving revolutionary color saturation , fine granularity and image stability by the state-of-the-art, innovative technologies. We believe that many photographers will use the new film for general-purpose.

Reference

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2)N.Matsuda,M.Kuramitsu,S.Kuwashima,S.Bando, IS&T's thirteenth International Symposium on Photofinishing Technologies, Final Program and Proceedings, 5 (2004).
3) M.Kuramitsu et al,Fujifilm Research & Deveropment, No.49 (2004).

Author Biography

Fumitaka Ueda received a master's degree from Tohoku University in 1989 and joined Ashigara Research Laboratories of Fuji Photo Film Co., Ltd. in the same year. He is currently involved in the development of color reversal films at Digital & Photo Imaging Materials Research Laboratories.