

## 2.6 PHOTOGRAPHIC FILM

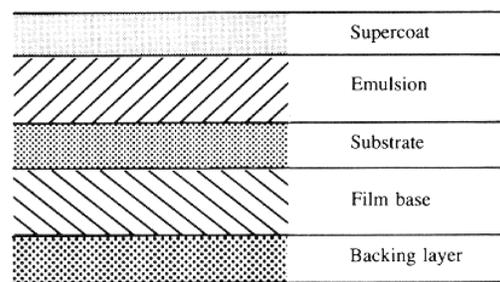
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Photographic film is an important element of image processing systems. It often is used as the recording medium for input images, and it is by far the most popular medium for recording output results. For these reasons, we conclude this chapter with a discussion of some basic properties of monochrome photographic film and their relation to image processing applications.

### 2.6.1 Film Structure and Exposure

Figure 2.23 shows a cross section of a typical photographic film as it would appear under magnification. It consists of the following layers and components: (1) a supercoat of gelatin used for protection against scratches and abrasion marks; (2) an emulsion layer of minute silver halide crystals; (3) a substrate layer to promote adhesion of the emulsion to the film base; (4) the film base or support, made of cellulose triacetate or a related polymer; and (5) a backing layer to prevent curling.

When the film is exposed to light, the silver halide grains absorb optical



*Figure 2.23 Structure of modern black-and-white film.*

energy and undergo a complex physical change. The grains that have absorbed a sufficient amount of energy contain tiny patches of metallic silver, called *development centers*. When the exposed film is developed, the existence of a single development center in a silver halide grain can precipitate the change of the entire grain to metallic silver. The grains that do not contain development centers do not undergo such a change. After development, the film is “fixed” by chemical removal of the remaining silver halide grains. The more light that reaches an area of the film, the more silver halide is rendered developable and the denser the silver deposit that is formed there. Since the silver grains are largely opaque at optical frequencies, an image of gray tones is obtained where the brightness levels are reversed, thus producing the familiar film negative.

The process is repeated to obtain a positive picture. The negative is projected onto a sensitive paper carrying a silver halide emulsion similar to that used for the film. Exposure by a light source yields a latent image of the negative. After development, the paper bears a positive silver image.

### 2.6.2 Film Characteristics

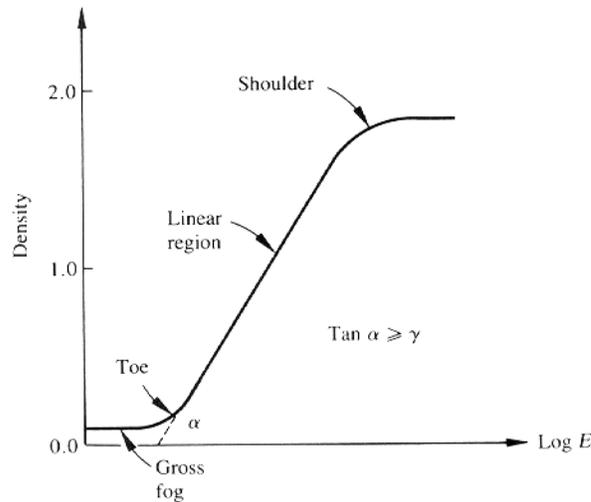
Of practical interest to the photographer are contrast, speed, graininess, and resolving power. An understanding of the effect of these parameters is particularly important in specialized applications, such as photographing the results obtained in an image processing system.

#### Contrast

High-contrast films reproduce tone differences in the subject as large density differences in the photograph; low-contrast films translate tone differences as small density differences. The exposure  $E$  to which a film is subjected is defined as *energy per unit area* at each point on the photosensitive area. Exposure depends on the incident intensity  $I$  and the duration of the exposure  $T$ . These quantities are related by the expression

$$E = IT. \quad (2.6-1)$$

The most widely used description of the photosensitive properties of photographic film is a plot of the density of the silver deposit on a film versus the logarithm of  $E$ . These curves are called characteristic curves,  $D$ -log- $E$  curves (density versus log exposure), and  $H$  &  $D$  curves (after Hurter and Driffield, who developed the method). Figure 2.24 shows a typical  $H$  &  $D$  curve for a photographic negative. When the exposure is below a certain level, the density is independent of exposure and equal to a minimum value called the *gross fog*. In the *toe* of the curve, density begins to increase with increasing exposure. Next is a region of the curve in which density is linearly proportional to logarithmic exposure. The slope of this linear region is referred to as the film *gamma* ( $\gamma$ ). Finally, the curve saturates in a region called the *shoulder*, and again density does not change with increasing exposure. The value of  $\gamma$  is a measure of film contrast: the steeper the slope, the higher the contrast rendered.



**Figure 2.24** A typical H & D curve.

General purpose films of medium contrast have gammas in the range of 0.7 to 1.0. High-contrast films have gammas on the order of 1.5 to 10. As a rule, films with relatively low gammas are used for continuous-tone reproduction; high-contrast films are used for copying line originals and other specialized purposes.

### Speed

The speed of a film determines how much light is needed to produce a certain amount of silver on development. The lower the speed, the longer the film must be exposed to record a given image. The most widely used standard of speed is the ASA scale. This scale is arithmetic, with the speed number being directly proportional to the film's sensitivity. A film of ASA 200 is twice as fast (and for a given subject requires half as much exposure) as a film of ASA 100. Some speed scales, such as the DIN system used in Europe, are logarithmic. Every increase of three in the DIN speed number doubles the actual speed. An ASA 50 film is equivalent to a DIN 18, an ASA 100 to a DIN 21, and so on.

General purpose films for outdoor and some indoor photography have speeds between ASA 80 and ASA 160; fine-grain films for maximum image definition between ASA 20 and ASA 64; high-speed films for poor light and indoor photography between ASA 200 and ASA 500; and ultraspeed films for very low light levels from ASA 650 and up.

### Graininess

The image derived from the silver halide crystals is discontinuous in structure, which gives a grainy appearance in big enlargements. The effect is most prom-

inent in fast films, which have comparatively large crystals; slower, fine-grain emulsions are therefore preferable in applications where fine detail is desired or where enlargement of the negatives is necessary.

### Resolving power

The fineness of detail that a film can resolve depends not only on its graininess, but also on the light-scattering properties of the emulsion and on the contrast with which the film reproduces fine detail. Fine-grain films with thin emulsions yield the highest resolving power.

### 2.6.3 Diaphragm and Shutter Settings

Regardless of the type of film used, proper camera settings are essential in obtaining acceptable pictures. The principal settings are the lens diaphragm and shutter speed.

In the lens diaphragm, a series of leaves increase or decrease the size of the opening to control the amount of light passing through the lens to the film. The diaphragm control ring is calibrated with a scale of so-called  $f$ -numbers, or stop numbers, in a series such as 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, and 32. The  $f$ -numbers are inversely proportional to the amount of light admitted. In the preceding series, each setting admits twice as much light as the next higher  $f$ -number (thus giving twice as much exposure) and half as much light as the next lower value. Shutter speed settings on present-day cameras also follow a standard double-or-half sequence. Typical speeds are 1,  $\frac{1}{2}$ ,  $\frac{1}{4}$ ,  $\frac{1}{8}$ ,  $\frac{1}{15}$ ,  $\frac{1}{30}$ ,  $\frac{1}{60}$ ,  $\frac{1}{125}$ ,  $\frac{1}{250}$ ,  $\frac{1}{500}$ , and  $\frac{1}{1000}$  sec. The faster the shutter speed, the shorter the exposure time obtained.

The diaphragm and shutter control the amount of light reaching the film by adjusting the light intensity and the time during which it acts. Different aperture–shutter speed combinations can thus yield the same exposure. For example, diaphragm  $f/2.8$  with  $\frac{1}{250}$  sec,  $f/4$  with  $\frac{1}{125}$  sec, and  $f/5.6$  with  $\frac{1}{60}$  sec, all yield the same exposure. However, the combination chosen for these two settings is not independent of the conditions under which a picture is taken or the characteristics of the film itself.<sup>†</sup> For example, when photographing a scene where depth of focus is of interest, the photographer should select an  $f$ -stop as high as possible to give the lens a “pin-hole” characteristic. For a given film, this requirement limits the range of shutter speeds that yield adequate exposures. In other applications, the shutter speed is the essential consideration. An example having image processing implications is the problem of photographing a television screen. In this case, the shutter speed must be set below the refreshing rate of the TV ( $\frac{1}{30}$  sec per frame) to compensate for the fact that the shutter is not synchronized with the refresh control signals. Typically,

<sup>†</sup> When  $T$  is long (e.g., greater than 1 sec.), we have to take into account a phenomenon called “reciprocity failure,” in which Eq. (2.6-1) no longer holds, and specific film tables have to be used to obtain the proper exposure settings.

$\frac{1}{8}$  sec is adequate, although slower speeds are often used in order to achieve frame integration. Many of the images in this book, for example, were photographed at  $\frac{1}{4}$  sec with Kodak Panatomic-X fine-grain film (ASA 32). The diaphragm settings were determined by using an exposure meter to measure the light intensity of each image.

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