There are many types of filters in machine vision that can be utilized to improve or change the image of the object under inspection. It is important to understand the different technologies behind the various types of filters in order to understand their advantages and limitations. Although there is a wide variety of filters, almost all can be divided into two primary categories, which will be introduced in the following sections: Colored glass filters and interference filters.

**Colored Glass Filters**
Colored glass filters are very common in machine vision, and are created by doping glass material with elements that selectively change their absorption and transmission spectra. The dopants vary based on which wavelengths are considered for transmission, and the manufacturing process is then nearly identical to standard optical glass manufacturing. Colored glass filters are advantageous for a couple of different reasons: They are of low cost when compared to interference filters and, more importantly, they do not demonstrate any shift in wavelength transmission when used at an angle, or with wide angle lenses.

However, colored glass filters also typically feature wide cut-on wavebands and do not have transmission profiles that are as sharp or accurate as interference filters. In addition, colored glass filters do not have the high transmission level of a coated interference filter. Figure 1 shows the transmission curves for several common colored glass filters. Note that the filters feature wide cut-on wavebands and have relatively shallow slopes describing their spectral transmission. Infrared (IR) cut-off filters can be either colored glass filters or a type of coated filter that is useful for both monochrome and color cameras in machine vision applications. Since the silicon sensors in most machine vision cameras are responsive to wavelengths up to approximately 1µm, any IR light incident on the sensor that may have been caused by overhead fluorescent lights or other unwanted sources can create a false color on the sensor. This degrades the overall color reproduction of the system, which is the reason why many color imaging cameras come standard with IR-cut filters over the sensor. With monochrome cameras, the presence of IR light will degrade the contrast of the overall image.

**Coated Interference Filters**
Coated filters typically offer sharper cut-on and cut-off transitions, higher transmission levels, and better blocking than colored glass filters. There is a broad range of different types of interference filters, from fluorescence filters to dichroic filters to polarization filters. Each coated filter undergoes a unique manufacturing process to ensure the proper performance. Wavelength-selective optical filters are manufactured by depositing dielectric layers of alternating high and low indices of refraction on a specific substrate. The surface quality and uniformity of the substrate establishes the baseline optical quality for the filter, along with setting wavelength limits where the transmission of the substrate material falls off. The dielectric layers produce the detailed spectral structure of a filter by creating constructive and destructive interference across a range of wavelengths, as well as providing much sharper cut-off and cut-on bands when compared to colored glass filters.

Many types of hard coated filters exist, such as bandpass, longpass, shortpass and notch filters, each with a specific blocking range and transmission range. Longpass filters are designed to block short wavelengths and pass long wavelengths. Shortpass filters are the opposite, blocking longer wavelengths and passing shorter wavelengths. Bandpass filters only pass a certain waveband, while blocking everything shorter and longer. The inverse of a bandpass is a notch filter, which blocks a narrow waveband while transmitting the longer and shorter. Typical transmission curves for these filters are shown in Figure 2.
Coated Interference Filters
Filters designed for deep blocking (high optical density) and steep slopes (sharp transitions from blocking to transmission) are used in applications where precise light control is critical. Most machine vision applications do not require this level of precision. Typically, any filter with an optical density (OD) of 4 or greater is more precise than required and adds unnecessary cost.

Application Example: Color vs. Monochrome
Consider the example shown in Figure 4, where gel capsules are being inspected. As shown, two red capsules are on the outer sides of a pair of green capsules under a white backlight. The goal is to sort the capsules according to their color. A simple setup with a monochrome camera (Figure 5) provides a contrast difference of only 8.7%, which is below the advisable contrast of 20%. In this particular example, minor fluctuations in ambient light, such as individuals walking past the system, can decrease the already low contrast value of 8.7% enough so that the system is no longer capable of operating properly. Several solutions to this problem exist: a bulky and costly light baffling system, the entire lighting scheme of the system can be reworked, or a filter can be added to enhance contrast between the green and red pills. In this instance, the simplest and most cost-effective solution is to utilize a green colored glass filter in order to improve the contrast between the two pills. As shown in Figure 6, the contrast improves from 8.7% to 86.5%. An increase of nearly a factor of 10. This examples illustrates how the combination of a filter with a monochrome camera can reliably solve applications that involve a limited number of colors. This way, the loss in resolution that comes along with using color sensors can be avoided.