METHOD AND APPARATUS FOR COLOR SPECTROPHOTOMETRY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for measurement of intensity of radiant energy and more particularly concerns measurement of energy intensities for analysis and determinatiton of color.

2. Description of Prior Art:

Objective measurement of color requires some type of light measuring device in a measurement that is quite complex, involving physics, physilogy and even psychology. The human eye operates upon an interplay or balance of three stimuli to sense color. Tristimulus values or weighting functions correspond to the three stimuli sensed by the human eye and of which stimuli the balance represents subjectively determined color. If the spectral distribution of light is analyzed, plotting intensity versus wave length, the resulting curve may be weighted according to the tristimulus functions to afford a complete description and predication of the measured color. Prediction of color resulting from the mixture of light from objects of two different colors or equal intensity is determined by use of chromaticity coordinates which may be computed from the tristimulus values. The chromaticity coordinates comprise a complete representation of the three parameters of color. Thus, tristimululs values may be calculated from measured values of spectal distribution. Chromaticity coorinates may be plotted from the calculated tristimulus values. Nevertheless, although chromaticity coordinates are of significant utility in analysis and comparison or colors, it is not possible to work back from chromaticity values to specify intensity values or color components required for matching color samples. Thus, the matching of color samples, that is, the analysis of a given sample for the purposes of producing additional samples of matching color, cannot be achieved from chromaticity coordinates, but must be based upon reflectance measurements.

For comparison of colors of two samples, a standard and trial sample for example, a transformation of the chromaticity coorindates based upon a formulation of MacAdam may be employed. According to the transformation and formulation of MacAdam, a color difference in MacAdam units may be computed. It is found that, because of peculiarities of the human color sensinig system, man is capable of much finer color difference resolution in the relatively low reflectance areas of the dark blues and reds than in the high reflectance areas of the bright yellows and greens, for example. Thus, as a practical matter, the darker the color, the easier it is for man to distinguish between related colors. Accordingly, not only is quantitative and objective color measurement and matching by instruments necessary and desirable, but such measurement must have maximum or at least equal precision at low light intensities reflected from the darker colors.

For standardization of color measurement, reflectance values are generally employed as percentages of reflection from a white standard. Such standards use white pigments of optimum reflectivity, such as titanium or barium sulfate. The reflectance ratios are measured and established as the ratio of intensity of reflectance from the color sample to the intensity of reflectance from the white standard, the ratio being measured and provided at each of a number of selected sample points of the optical spectrum.

A common commercial instrument employs a stabilized light bulb and optics directing a beam of light to a sample with a number of filters interposed one after the other. Filtered and reflected light is picked up by a photosensitive device of which the output is employed to indicate intensity of the light impinging thereon. More complex spectral photometers are employed to sweep the reflectance measurement through the color spectrum by illuminating the sample and the white standard with light of successively different wave lengths from a movable prism or grating. In some of these instruments, the resulting signals are weighted according to the tristimulus values which are then directly available in digital form. In both of these types of systems, that using the grating and that using the filter wheel, energy of light reflected from the targets is then measured by a light-sensitive device, such as a photomuliplier tube. These systems use both a white standard and the color sample and employ separate optical paths for light reflected from the standard and sample. Light in these paths is "chopped" and transmitted along parallel paths to the light-sensitive device wherein the measurements are made. Both optical and elecronic null systems have been used to determine the ratio of energy from the sample and from the white standard to indicate reflectance percentages.

The U.S. Pat. to Razek et al, No. 1,964,365, shows a measurement measurment system employing illumination by narrow parts of the spectrum and either manually moving a sample and a white standard or using two ports and two photosensors in a diffusing sphere. The U.S. patents to B. D. Herderson, No. 2,992,588, and F. Grum et al, No. 3,512,895, are illustrative of spectrophotometers for reflectance measurement employing a monochrometer of which the output is chopped to alternately illuminate a sample and a standard with the desired color or white light.

Systems presently in use suffer from a number of defects. The point in the optical spectrum that is employed for measurements at any given time depends upon either the physical positioning of the filter wheel or the mechanical positioning of a grating. Therefore, the exact spectral wave length is subject to error, since mechanical parts tend to wear and electronic positioning circuits tend to drift. The various positions of a filter wheel or movable grating may not be precisely repeatable. Particularly for those samples having curves with relatively steep or near vertical portions (in the graph of intensity vs. wave length), a slight variation in the wave length of the narrow band of illumination may give rise to major error.

Use of separate optical paths for light from the sample and from the white standard in prior systems also gives rise to error since the two paths are difficult to precisley match. Additional optical elements are provied in order to first separate the light into two paths and then again direct the light to the common photosensitive device. The different paths may be subject to differing amounts of stray light and to differing aging or drift characteristics.

Still another disadvantage of prior systems is of greatly increased significance in the light of the previously described ability of the human eye to achieve finer resolution for dark colors than for bright colors. Reflectance measurements for dark colors are based