DOUBLE-BEAM SPECTROPHOTOMETER

BACKGROUND OF THE INVENTION

This invention relates to a double-beam spectrophotometer provided with an integrating sphere for measurement of the spectral reflection characteristics of a sample.

Generally, the reflection of light from the surface of an object comprises diffuse reflection and specular reflection, so that the light reflected from the surface is a mixture of both diffusely reflected and specularly reflected components.

There are two methods of measuring the light reflected from the surface of an object by using an integrating sphere.

One is to measure the diffuse reflection component only and the other is to measure the total reflected light including both the diffuse reflection component and the specular reflection component.

When the above two methods of measurement are conducted by using conventional double-beam spectrophotometers provided with a single integrating sphere, various difficulties are encountered.

One conventional spectrophotometer is provided with an integrating sphere such as shown at IS in FIG. **1**. The sphere IS is formed with a pair of inlet windows WI_R and WI_S, through which a reference light beam L_R and a sample light beam L_S parallel with each other are introduced into the integrating sphere IS. The integrating sphere is also formed with an outlet window WO, outside which a photodetector not shown is arranged to receive the light from inside the integrating sphere. In the sphere there are a sample to be measured (which will be referred to merely as the sample and designated by S) and a sample to be used as the reference or standard (which will be referred to merely as the reference and designated by R) so arranged that their respective surfaces face inwardly of the integrating sphere and are inclined relative to the sample and reference beams L_S and L_R respectively so that the specular reflection components of the two incident light beams reflected from the reference and sample surfaces hits a particular area on the interior surface of the integrating sphere.

When only the diffuse reflection component of the light incident on the sample S is to be measured, the specular reflection component thereof is removed by a light trap TR located in the above-mentioned particular area of the interior surface of the integrating sphere. When the total reflected light including the diffuse reflection and specular reflection components is to be measured, the light trap TR is replaced by a diffusely reflecting white plate PL.

The above-mentioned conventional arrangement, however, has the following defects: Firstly, since the surfaces of the sample and the reference facing inwardly of the integrating sphere IS are not tangential to the sphere, the interior surface of the sphere is not completely spherical so that complete integration cannot be attained. Secondly, in order to conduct two different kinds of measurement, a light trap and a white plate must alternatively be used, so that the operator of the instrument may make a mistake in exchanging the two members. Thirdly, it is practically quite difficult that the interior surface of the integrating sphere and that of the white plate should continuously have substantially the same characteristic with respect to reflection of

light as time passes, so that errors are likely to be introduced into the results of measurement.

Another conventional spectrophotometer is provided with a single integrating sphere as shown in FIGS. **2***a* and **2***b*, wherein the same reference symbols as in FIG. **1** designate corresponding parts or elements, so that no explanation will be given to them. When the diffuse reflection component only is to be measured, both the sample S and the reference R are so mounted on the integrating sphere IS that the sample and reference beams L_S and L_R introduced into the sphere through the respective inlet windows WI_S and WI_R impinge on the inner surfaces of the sample and the reference perpendicularly thereto so that the specular reflection components from both the surfaces go out of the integrating sphere through the inlet windows.

When the total quantitity of the reflected light including both the diffuse reflection component and the specular reflection component is to be measured, a spacer SP is interposed between the sample S and the integrating sphere IS thereby to set the sample S aslant relative to the sphere, so that the specular reflection component of the light reflected from the sample hits the inner surface of the integrating sphere so as not to come out therefrom.

The arrangement, however, has the following defects: Firstly, with the spacer SP interposed between the sample and the integrating sphere, the sample is set aslant and positioned outwardly of a plane tangential to the integrating sphere, so that a portion of the diffuse reflection component of the light reflected from the sample hits the spacer, thereby to prevent correct measurement by the integrating sphere. Secondly, the spacer must be attached to or detached from the integrating sphere, depending upon the kind of measurement to be made. The operation is certainly troublesome.

SUMMARY OF THE INVENTION

Accordingly, the object of this invention is to provide a double-beam spectrophotometer having a single integrating sphere which eliminates the above-mentioned and other defects of the conventional spectrophotometers of this type.

The spectrophotometer constructed in accordance with this invention is provided with an integrating sphere formed with a first pair of windows in which a sample and a reference are set so as to be tangential to the integrating sphere and a second pair of windows through which the sample beam and the reference beam are introduced into the integrating sphere so as to impinge on the sample and the reference, respectively, set in the first pair of windows.

In a preferred embodiment of the invention, one of the first pair of windows and the corresponding one of the second pair of windows are so arranged that a straight line connecting the center of the former one window and that of the latter corresponding one window does not pass the center of the integrating sphere. With this off-center arrangement, the light beam introduced into the integrating sphere through the latter one window impinges aslant on the sample or reference set in the former one window.

The sample and the reference set in the first pair of windows are exchanged in accordance with the kind of measurement. In other words, the positions of the sample and the reference mounted on the integrating sphere