Sphere vs. 0°/45°

A discussion of instrument geometries and their areas of application

Introduction

When purchasing a spectrophotometer for color measurement, one of the choices that must be made is the geometry of the instrument; that is, whether to buy a spherical or 0°/45° instrument. In this article, we will attempt to provide some information to assist you in determining which type of instrument is best suited to your needs. In order to do this, we must first understand the differences between these instruments.

Simplified schematics of instrument geometries

We will begin by looking at some simple schematic drawings of the two different geometries, spherical and 0°/45°.

Figure 1 shows a drawing of the geometry used in a 0°/45° instrument. The illumination of the sample is from 0° (90° from the sample surface). This means that the specular or gloss angle (the angle at which the light is directly reflected) is also 0°. The fiber optic pick-ups are located at 45° from the specular angle.

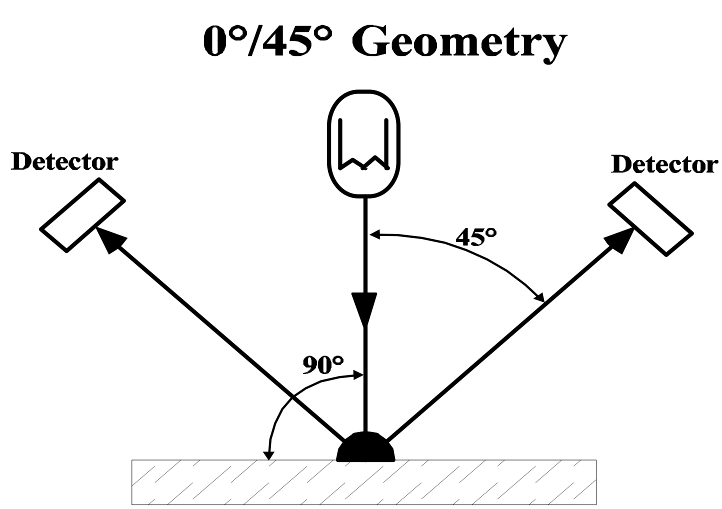

Figure 1

Figure 2 shows a drawing of the geometry used in an 8° diffuse sphere instrument. The sphere wall is lined with a highly reflective white substance and the light source is located on the rear of the sphere wall. A baffle prevents the light source from directly illuminating the sample, thus providing diffuse illumination. The sample is viewed at 8° from perpendicular which means that the specular or gloss angle is also 8° from perpendicular. You should note that this is where the specular port is located. Additionally, the reference beam port monitors the sphere wall to account for changes in illumination.

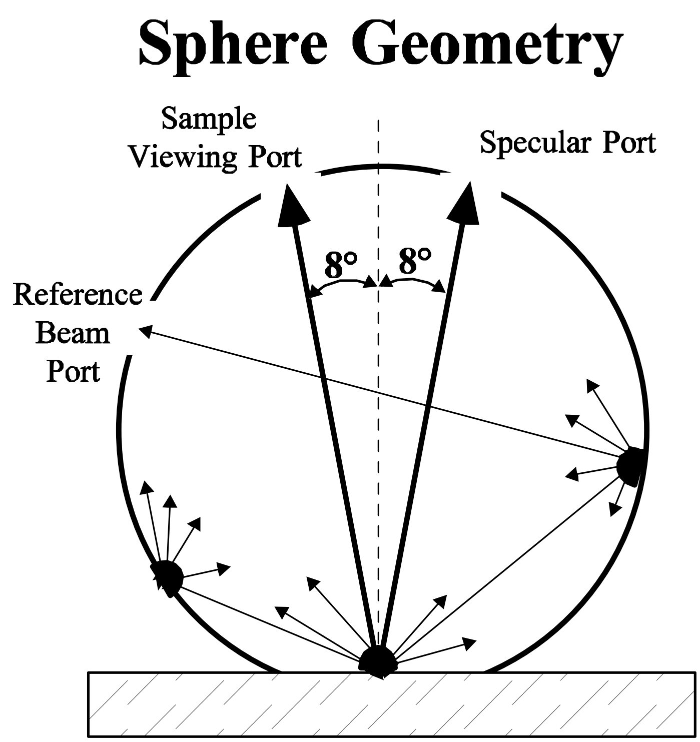

Figure 2

Now that we have seen the differences in geometries, we need to understand how these differences affect the way the spectrophotometer "sees" color.

Specular included vs. specular excluded

Spherical spectrophotometers can provide reflectance measurements in two different ways, specular included and specular excluded. A specular included reading would include the specular or gloss component (also known as the 1st surface reflectance), and a specular excluded reading would exclude the specular or gloss component. If we refer back to Figure 1, we can see that a 0°/45° instrument is only capable of specular excluded readings. Looking at the sphere in Figure 2, we should note the specular port, which can be opened to allow the specular component to escape, thus providing us with a specular excluded reading. The sphere is also capable of reading with the specular port closed, providing us with a specular included reading.

Figure 3 below shows us two reflectance curves of a glossy sample. Note the increased reflectance values for the sample measured specular included. If we were to measure a matte surface both included and excluded we would see nearly identical curves.

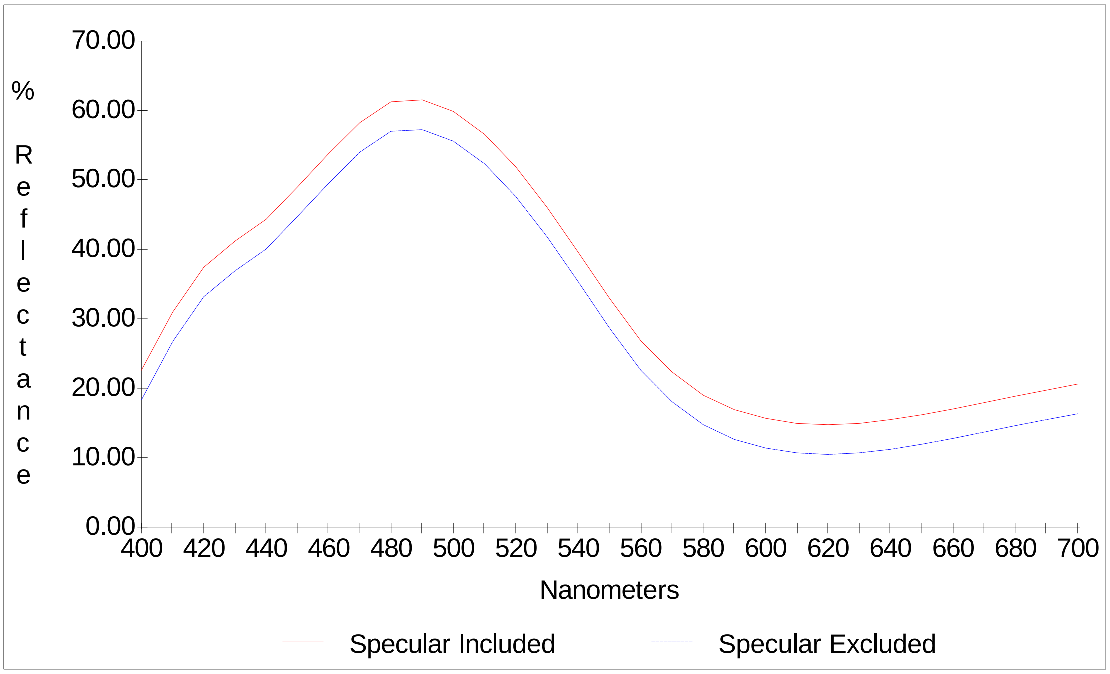

Figure 3

We should remember, that the specular excluded reading from a sphere instrument will vary from a reading from a 0°/45°. The 0°/45° truly excludes all of the gloss, while the specular port in a sphere may not always allow all of the gloss to escape. This is true as the specular port size must be limited in order to provide proper "mixing" of light from the sample surface.

Varying Surfaces

Do I need a 0°/45° or sphere instrument? Do I need to measure specular included or excluded? Is it important that I be able to measure both included and excluded? Looking at some examples of how light reflects on different surfaces may help us to answer these questions.

Figure 4 shows us a how light reflects on a matte finish of a regular surface. We can see that the amount of light reflected remains essentially constant at all angles. If we were to measure this with both included and excluded, 0°/45° and sphere, we would obtain nearly identical results.

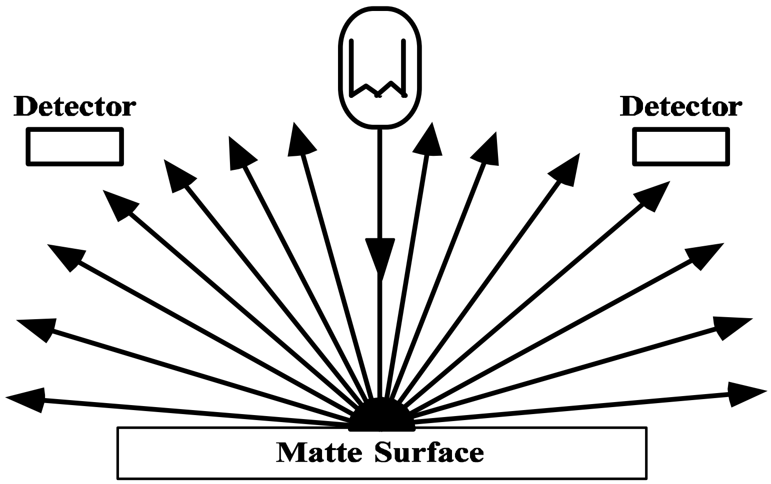

Figure 4

Figure 5 shows us how light reflects on an irregular or textured surface. We can see that the amount of light reflected varies greatly at differing angles. If we measure this type of surface with a 0°/45° instrument, we may get a wide variety of readings depending on measurement location. In *Instruments for the Measurement of the Colour of Transparent and Opaque Objects*, David Patterson states:

"The greater part of the radiation emerging from the sample is lost due to diffusion in many directions. This loss can be reduced by the use of an integrating sphere".

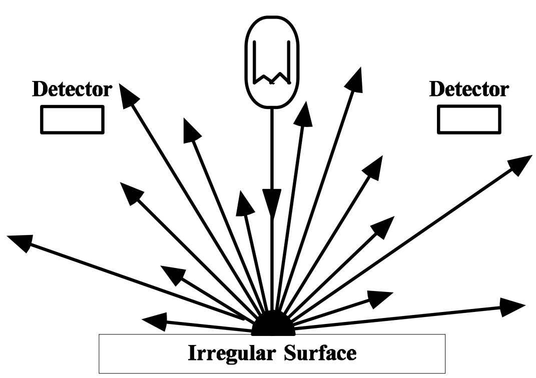

Figure 5

Figure 6 shows us how light reflects on a high gloss, regular surface. We can see that the majority of the light is reflected at or near the specular angle. If we measure this type of surface with a sphere, we will get a large variation between specular included and excluded readings.

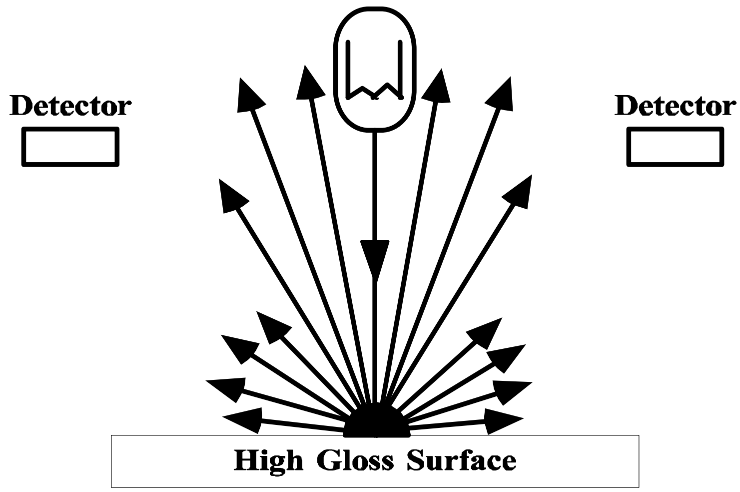

Figure 6

In our day to day working, we may encounter any or all of these types of surfaces. Choosing which instrument is best for our needs involves identifying which surface(s) will be most prevalent.

Choosing an instrument

A 0°/45° instrument has an advantage in measuring regular, non textured surfaces, since it can provide us with a truly specular excluded reading. Billmeyer & Saltzman in *Principles of Color Technology* state:

"*The human observer is almost invariably interested in the appearance of the sample with the specular component excluded, for this gives him the most information about its color. Unfortunately, most color measuring instruments use integrating sphere geometry, and the inability of the integrating sphere to exclude the specular component completely for any but very highly glossy samples poses a serious problem.*"

However, this is often not the case. Many times samples have irregular or textured surfaces, or vary greatly in gloss level. Which instrument then gives me the best information?

As Billmeyer & Saltzman stated, we are usually interested in the appearance of a sample, and measuring with specular excluded shows me an appearance difference. If however, we want to detect a pigmentation difference, or compare different textures of the same material, specular included provides us the required information. For example, figure 7 shows us four different readings from one piece of plastic. One side of the plastic is smooth while the other side is highly textured. Since the readings were taken on a single piece of plastic, we know they are pigmented the same. The specular included readings show us they are the same color, while the specular excluded readings show us a large appearance difference.

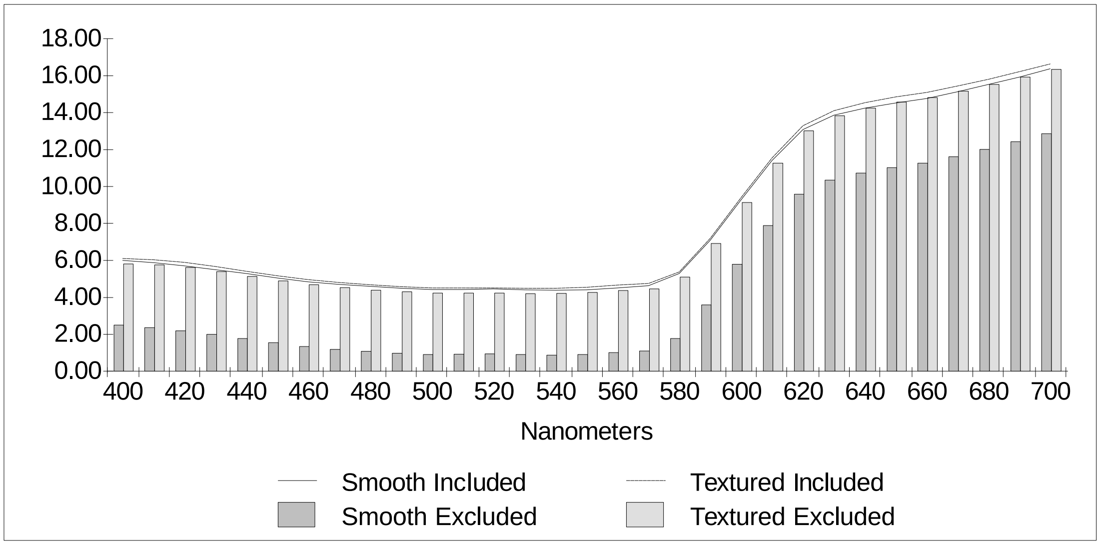

Figure 7

Additional considerations

1. You may have some customers who require a specular included tolerance and some who require a specular excluded tolerance.

2. The texture and/or gloss of your samples varies greatly (this is especially true with textiles). To truly evaluate the color without respect to gloss or texture requires an included reading.

3. Many plastic moldings have various textures within the same piece. If you want to compare those surfaces for color variation, you will need an included reading.

Each of these examples would require a sphere instrument. The ability of the sphere instrument to measure both included and excluded can be very beneficial if you want to be able to look at both color and appearance.

We should not, however, discount the capability of the 0°/45° instrument to provide us with accurate measurements in many situations, including the following;

1. Comparing samples of a common texture or gloss (i.e. injection molded parts).
2. Paint drawdowns where gloss is not a factor to be considered.
3. Printed materials, where a 0°/45° is the conventional measurement geometry.

References

Billmeyer, F.W. Jr., & Saltzman, M., Principles of Color Technology, 2nd Edition, John Wiley & Sons, New York, NY, 1981.

Johnston-Feller, R.M., Color Measuring Instruments: A Guide to Their Selection, from Color Technology in the Textile Industry, AATCC, Research Triangle Park, NC, 1983.

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