A diffuse reflecting material for optical studies

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Our laboratory developed a new diffuse reflecting material several years ago. It has significantly higher diffuse reflectivity in the visible than that of the best previous diffuse reflector known as Spectralon. At 532 nm this new diffuse reflector has provided a 99.92% diffuse reflectivity, compared to only 99.4% for Spectralon. At first glance that may not seem much better, but the relevant parameter is 100% minus the reflectivity; and on that basis, the new material is a factor of 8 better! In the near ultraviolet the improvement is even better. At 250 nm Spectralon has a diffuse reflectivity of 94%, whereas this new diffuse reflecting material has a reflectivity that exceeds 99.6% at 250 nm.

This new material is opening new research vistas. It can be used to make a state-of-art integrating cavity (a closed container whose wall is the diffuse Lambertian reflector). When a sample is placed in an integrating cavity and illuminated by a beam of light, the result of the multiple reflections of the light from the cavity walls is that the light makes many, many transits through the sample, i.e. the effective path length through the sample far exceeds the dimensions of the sample. For example, the effective path length through a sample that fills a spherical cavity of radius 7.5 cm is about 100 meters when the wall reflectivity is 99.9%. The result is a very high sensitivity to very weak absorption as well as to other light-matter interactions. In addition, since the diffuse reflecting walls of the cavity produce an isotropic illumination of the sample, the spectral absorption measurements are not affected by light scattering in the sample. The latter is very important in many cases; e.g. measurements of water samples, biological samples, etc. This technique was recently used to make the first reliable measurements of the optical absorption of pure water into the UV down to 250 nm.

In another research direction, integrating cavities made from this new diffuse reflecting material have been used to significantly enhance both the excitation and the 4 π collection of the Raman fluorescence from a sample. The detection of sub-femto molar concentrations of urobilin were demonstrated (this corresponds to a capability of detecting the presence of 10 ml of urine in a typical swimming pool).

An exceptionally high sensitivity technique for absorption spectroscopy is cavity ring down spectroscopy (CRDS) in a 2 mirror cavity. Due to the high diffuse reflectivity of this new material, CRDS in an integrating cavity (ICRDS) is now possible. ICRDS opens another new research capability by providing extremely sensitive and accurate direct spectral absorption measurements of both a sample and any particulates suspended in it, while being unaffected by the scattering in the sample. ICRDS has recently been demonstrated in measurements of the very weak spectral absorption of highly scattering biological samples (e.g. at 600 nm the scattering coefficient was more than 500 times larger than the absorption coefficient).