A novel optical diffuser with potentially higher spectral flatness in the near infrared region

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We have reported a new optical diffuser that has potentially more spectrally neutral than existing optical diffuser in the near infrared region where inherent molecular absorption structure due to water or base material shows strong wavelength dependence that causes big uncertainty. Spectrophotometric comparison has been revealed that the Al_2O_3 optical diffuser processed with plasma powder spraying have relatively flat spectral properties over the entire near infrared region. Basic optical properties of plasma-sprayed Al_2O_3 optical diffuser and its advantage for spectrophotometry has been discussed.

INTRODUCTION

Reflection-type optical diffusers are widely used as a reference material to calibrate various types of spectrophotometers and related instruments. They are also used as key optical components such as the material to finish the surface for an integrating sphere, or an optical target to convert irradiance to radiance. So far, many kinds of optical diffusers are commercially available and their basic reflection properties have been studied in detail.

Recently applications that require accurate spectrophotometry have been extended beyond the visible region where conventional reflection colorimetry is applied. One of the fields that attract attention is the application that makes use of near infrared radiation such as gas analysis, optical communication, remote sensing including LiDAR (Light Detection and Ranging) and non-invasive optical diagnosis. To calibrate a spectrophotometer in the near infrared region for such application, one of the technical issues is that optical diffusers usually show absorption bands mainly due to inherent molecular vibrational structure by water or base material that result in strong wavelength dependence with respect to reflectance and greatly affects the measurement uncertainty.

We have intensively studied a new approach to prepare a material applicable to optical diffuser based on thermal spraying processes, which is one of the common industrial processes for material coating on metals or ceramics. Main objectives are to improve critical optical properties such as optical durability and mechanical strength. So far, some novel optical diffusers with peculiar optical properties have been developed [1], and among them we have achieved the optical diffuser with more than 50 times UV resistance and around 10 times mechanically stronger surface compared with painted $BaSO_4$ surface [2]. Further instrumental and process improvement for better optical properties are in progress.

A series of optical characterization for various prototype samles made by thermal spraying has revealed that the optical diffuser made from Al_2O_3 processed with plasma powder spraying shows high spectral flatness especially in the near infrared region compared with existing optical diffusers. In this study, basic infrared optical properties have been examined for plasma-sprayed Al_2O_3 optical diffusers to find out the relationship with material parameters and to discuss their advantage as reflectance standards or material for an integrating sphere used for the measurement in the near infrared region.

EXPERIMENTAL

The plasma-sprayed samples were prepared by use of an apparatus of plasma-sprayed coating for general industrial use such as abrasion-resistant overcoat layer on a metal or a ceramic, as shown in Fig.1. Al_2O_3 powder with reagent grade was

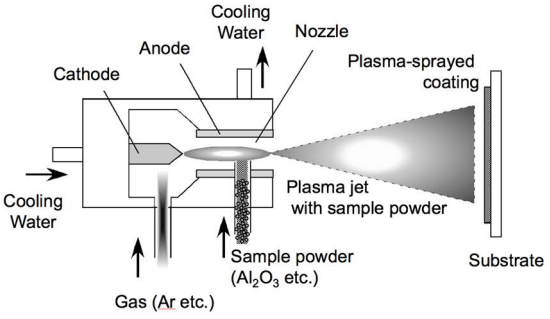

Figure 1. Schematic diagram of the apparatus and the process for plasma powder spraying

installed in the chamber of the plasma-spray apparatus and injected into electrically generated plasma flame based on Ar. The accelerated plasma jet with Al_2O_3 was hit and deposited on 50 mm x 50 mm x 3 mm Al substrate to form diffusing surface. The approximate thickness of the samples onto the substrates was from 0.20 mm to 0.60 mm depending on the spraying condition. The purity of the Al_2O_3 powder used in this study is more than 99.8 %.

For comparison of the reflection properties in the near infrared region, the following optical diffusers used as reflectance standard mainly for colorimetry were prepared.

- Pressed and sintered PTFE (PTFE resin)
- Painted $BaSO_4$ with polyvinyl alcohol (PVA)
- Pressed $BaSO_4$
- Matte ceramic tile
- Matte Opal glass

Spectral reflectance of each sample was measured using a calibrated spectrophotometer (Perkin-Elmer Inc., Lambda 900) attached with a 150 mm integrating sphere. The measured wavelength range is from 800 nm to 2500 nm and the measurement geometry is 8°/di and 8°/de, respectively.

RESULTS AND DISCUSSION

Fig.2 shows spectral diffuse reflectance of major samples prepared in this study. The measurement geometry is 8°/de geometry. As is clearly observed in Fig.2, plasma-sprayed Al_2O_3 optical diffusers shows spectrally flatten reflection properties over the entire near infrared region (from 800 nm to 2500 nm) with maximum reflectance difference of around 3 %. The spectra of all the other existing optical diffusers show some dips that correspond to the reflection change of 5 % to more than 10 % within 100 nm bandwidth. For $BaSO_4$-based diffusers and the matte ceramic tile, the observed dips would be mainly attributable to the vibrational absorption of water molecule attached within the crack and dent of the diffusing surface. Contribution by crystal water might be another cause. Spectral dips observed for PTFE resin would be attributed to the vibrational absorption by PTFE itself. Matte opal shows much broader spectral dependence that would be caused by translucency increased in proportional to the wavelength.

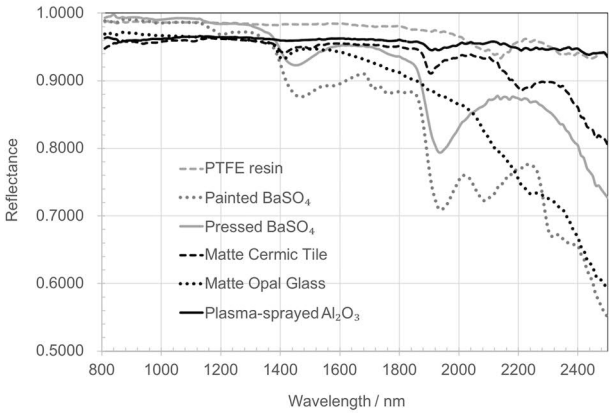

Figure 2. Comparison of spectral diffuse reflectance in 8°/de geometry of the samples used in this study

It can be assumed that the plasma-sprayed Al_2O_3 optical diffuser can also contain water molecule within its surface or as crystal water. However, the spectral analysis in this study showed much less contribution of water for this type of sample, which would be the benefit of plasma-spraying process owing to its high temperature. In addition, controlling the particle size of Al_2O_3 powder during the spraying process is one of the requirements to keep efficiency of the plasma process, which would highly contribute developing relatively uniform and minute surface with less crack and dent.

As was discussed previously [1], when the thickness of the plasma-sprayed Al_2O_3 optical diffusers is not enough, clear wavelength dependence due to the effect of translucency has appeared. The longer the wavelength is, the lower the reflectance becomes. It is found that such translucent effect becomes almost negligible when the coating thickness is beyond 0.40 mm.

CONCLUSION

We have found that the plasma-sprayed Al_2O_3 optical diffuser has better spectral properties especially in terms of spectral flatness in the near infrared region compared with other types of existing optical diffusers. Spectral flatness that would mainly come from the ultra-heating process and uniform surface structure both of which are prominent features of the plasma spraying process.

REFERENCES

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