Planck's Law Base Function for Background Correction of Remote Sensing with Compact and High-Sensitivity Mid-Infrared Spectrometer

Satoru Adachi[1], Tomoya Kitazaki[1], Junya Iwaki[1], Kosuke Nogo[1], Kenji Wada[2], and Ichiro Ishimaru[1]
Faculty of Engineering and Design, Kagawa University[1], Faculty of Medicine, Kagawa University[2]
E-mail: ishimaru.ichiro@kagawa-u.ac.jp

Ⅰ. Abstract

We aim to perform remote sensing in outdoor environments using a compact high-sensitivity mid-infrared spectrometer. Infrastructure facilities such as gas transportation lines and bridge piers are exposed to the natural environment and these facilities deteriorate because of corrosion. To solve this problem, maintenance management technology that enables nondestructive and noncontact measurements to be performed over a wide area is required. Previously, spectroscopic measurements of salt damage to concrete and other materials using light in the near-infrared band have been reported (Watanabe et al., 2019). However, at common temperatures (300 K), these objects emit little light in the near-infrared band, according to Planck's law. Therefore, it is necessary to illuminate each object and measure the intensity of the transmitted or reflected light, and this leads to issues with instrument portability and illumination uniformity over wide areas. Therefore, we perform spectroscopic measurements using mid-infrared light, where the object emits light at a temperature equivalent to 300 K and illumination is not required. In this report, we propose a new method for background correction, which has been problematic in mid-infrared spectroscopy. We verified the usefulness of the proposed method via experiments using dimethyl ether (DME) gas and confirmed the reduction in gas concentration over time.

Ⅱ. Concept of background correction method using base function of Planck's law

Figure 1 (a) shows the concept for the Planck’s law based-background correction. In this correction, there are two mode types: the emission mode, in which the background spectral characteristics are aligned along the lower of the measured spectral characteristics, and the absorption mode, in which the background spectral characteristics are aligned along the envelope. In the former mode, the emission from the measurement target can be detected by predicting the monochromatic radiation of a blackbody at the same temperature based on the measurement target’s spectral characteristics. In the latter mode, the amount of light absorbed by the measurement target can be detected by predicting the light from background sources such as pipes from the light transmitted through the measurement target. However, in the actual system, the spectral characteristics are detected through a camera based on the radiance, which is indicated by Planck's law. Therefore, the background can be estimated by multiplying the camera’s sensitivity characteristics by the measurement target’s spectral characteristics to determine the temperature to be substituted into Planck's law. Figure 1 (b) shows the experimental environment. The midinfrared spectrometer was placed 780 mm from the light source, which is a blackbody set at 573 K. DME gas was then injected in front of the blackbody for 15 s, and data were acquired five times in successive measurements at 16 s intervals. Figure 1 (c) shows the results for measurement of the DME gas using the proposed method. The reduction in the amount of DME gas with elapsed time confirms the usefulness of the proposed method.

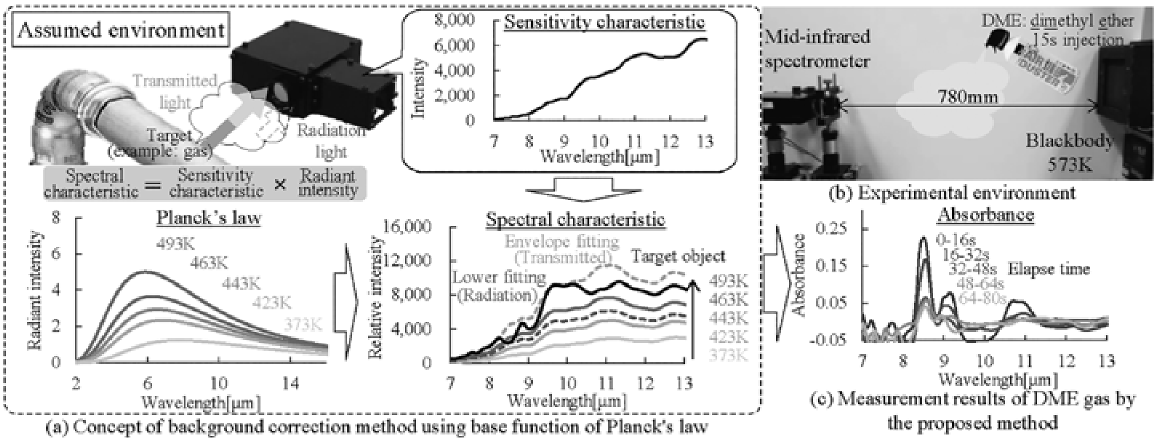

Fig. 1 Planck's law base-function for background correction and measurement results of DME gas

Ⅲ. References

Watanabe, A., Furukawa, H., Miyamoto, S., & Minagawa, H. (2019). Non-destructive chemical analysis of water and chlorine content in cement paste using near-infrared spectroscopy. *Construction and Building Materials*, 196, 95–104.