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Detection of SF_6 in soundproof windows

Hans-Fridtjof Pernau[1], Carl Basler[1], Gerrit Stiefvater[1], Jürgen Wöllenstein[1,2], Katrin Schmitt[1,2]
[1] Fraunhofer Institute for Physical Measurement Techniques IPM, Georges-Köhler-Allee 301;
79110 Freiburg Germany,
[2] Department of Microsystems Engineering - IMTEK, Georges-Köhler-Allee 102;
79110 Freiburg Germany

hans-fridtjof.pernau@ipm.fraunhofer.de

Summary:

SF_6 has a greenhouse effect 25,200 times greater than CO_2 and was widely used as a gas in soundproof windows until 2006. In 2020, Germany was responsible for 55.3 % of SF_6 emissions within the European Union. Without emissions from soundproof windows, this value could be reduced to 14.6%. Since the filling of most windows is unknown, a reliable detection method is required to identify SF_6-filled windows to be able to safely extract and recycle the filling when disposing of them. In our study, we were able to identify LIBS (Laser-Induced Breakdown Spectroscopy) as the most promising technology for identifying filling gases in soundproof windows and show a way of what a mobile detection and recovery unit for SF_6 could look like.

Keywords: SF_6, greenhouse effect, Raman spectroscopy, LIBS, remote gas detection

Introduction:

Due to its unique physical properties, SF6 has been a widely used gas in technical applications in transformer stations, wind turbines or in soundproof windows. It has a high molecular mass, low thermal conductivity, prevents sparking and it is very long-term stable to heat and UV light. The last point is particularly important because it lasts more than 3,500 years in the atmosphere and has a more than 25,000 times greater impact on the greenhouse effect than CO2. Therefore, SF6 should not be released into the environment, but should be recovered and then decomposed or recycled in a controlled manner.

Materials and Methods:

A common way to measure the SF_6 content in a gas mixture is by means of infrared absorption spectroscopy, as it has a very distinct absorption peak around 10.56 µm [1]. Using this method, SF_6 can be detected in the ppm range in air. Since ordinary window glass (boron float glass) is not transparent in this wavelength range, IR absorption spectroscopy is unsuitable for carrying out measurements on an intact window.

Using a thermal conductivity measurement or measuring the speed of sound may give an indication of SF_6 in the window filling, but a similar signal can be produced by Ar, Kr or Xe. For this reason, we used both Raman spectroscopy and LIBS to identify a suitable detection method to measure the SF_6 content, including possible additional gas compounds.

Results:

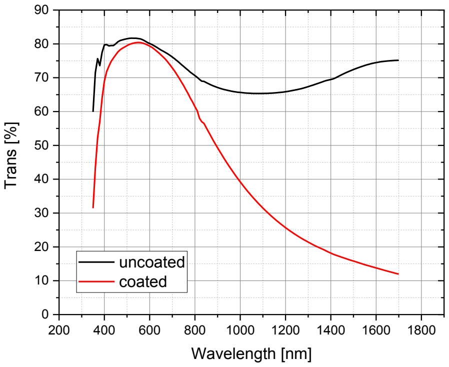

Fig. 1. Transmission of an uncoated and a coated double-glazed window. The reflective coating prevents IR radiation above 800 nm from penetrating the glass.

The first active Raman fundamental frequency of SF_6 can be found at 774.3 1/cm [2]. Since also N_2 and O_2 are Raman active, it is possible to detect the SF_6 content in a matrix of air. Unfortunately, other potential filling gases like Ar, Kr, and Xe are not Raman active. The first Raman fundamental frequency of SF_6 can be measured through an ordinary glass window with a thickness of 4 mm with a minimum laser power of 50 mW at a wavelength of 534 nm (see Figure 2).

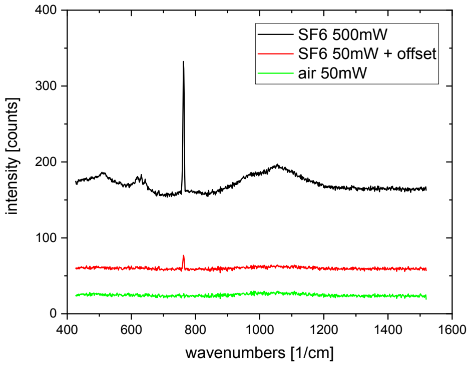

Fig. 2. Measurement of the first Raman fundamental frequency of SF_6 through a 4 mm thick window glass. Using a laser power of 50 mW, the Raman signal can be identified (the plot of the measured values at 50 mW is provided with an offset on the y-axis for a better overview)

The second investigated measurement technique was LIBS. A nanosecond laser pulse at 1064 nm thereby ionizes the matter within the focus of the laser beam, which forms a plasma and emits light. The emitted light spectrum is unique for each atom. Therefore, it is possible to detect all gases due to their individual LIBS signal.

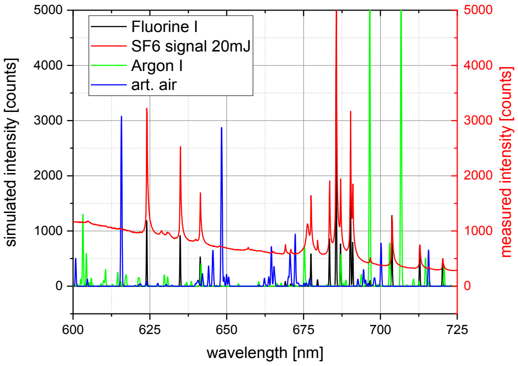

Fig. 3. Measured LIBS signal of a SF_6 gas filling inside a double-glazed window (red). Simulated LIBS spectra of fluorine (black), argon (green) and synthetic air (blue).

As the laser pulse requires an energy of at least 11 mJ to initiate the plasma in the focal point of less than 100 µm size, the challenging task is to focus the beam through the 4 mm thick normal window glass without initiating the plasma formation inside the glass. We were able to detect the SF_6 filling within the window, as shown in Figure 3 (red) along with simulated LIBS spectra calculated with the NIST LIBS simulation tool [3]. The tilt within the measured spectrum is due to thermal shift and the measurement setup and can be subtracted (the data shown is as measured). The measured spectrum is clearly dominated by the first ionization of fluorine, which is shown in black. Low intensity absorption bands at 616, 648 and 664 nm indicate that the gas filling in the window may have been contaminated with some air (blue, simulated spectrum).

Outlook:

It was found that all gaseous components of a filling in soundproof windows can be measured using LIBS in a laboratory setting. The next steps will involve developing a portable device that can be used on a renovation construction site. In addition, a system for direct extraction of SF_6 from the windows is presented to reduce the risk of unwanted release when the windows are removed and to enable professional disposal. In our presentation, the latest results on the LIBS measurement setup and the recovery system will be shown and discussed.

References:

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Authors Contributions:

C. Basler, G. Stiefvater and H.-F. Pernau performed the measurements. H.-F. Pernau worked on alternative detection possibilities, the SF_6 recovery system and wrote this article. K. Schmitt and J. Wöllenstein proofread and supervised this work.

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Conflict of interest:

There are no conflicts of interest.