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EVALUATION OF 3D MEASUREMENT USING CT-TDLAS

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In order to satisfy the requirements of high quality and optimal material manufacturing process, it is important to control the environment of the manufacturing process. Depending on these processes, it is possible to improve the quality of the product by adjusting various gases. With the advent of the TDLAS (Tunable laser absorption spectroscopy) technique, the temperature and concentration of the gases can be measured simultaneously. Among them, CT-TDLAS (Computed tomography-tunable diode laser absorption spectroscopy) is the most important technique for measuring the distributions of temperature and concentration across the 2-dimensional planes. In this study, suggest a 3-dimensional measurement to consider the irregular flow of supplying gases. Used the SMART (simultaneous multiplicative algebraic reconstruction technique) algorithm among the CT algorithms. Phantom data sets have been generated by the using Gaussian distribution method. It can be shown expected temperature and concentration distributions. The HITRAN database in which the thermo-dynamical properties and the light spectra of H_2O are listed were used for the numerical test. The

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relative average temperature error ratio in the results obtained by the SMART algorithm was about 3.2% for temperature. The maximum error was 86.8K.

Keywords: Computed tomography-tunable diode laser absorption spectroscopy; Temperature; Concentration; Data Reconstruction; Exhaust gas.

1. Introduction

The control environment of the manufacturing process is a very important factor in the real industry. The oxidation process is very important in the process of manufacturing semiconductors. A wet oxidation method is used to increase the growth rate of the oxide film in these oxidation steps. Important factors in the wet oxidation method are temperature, pressure, concentration, time and so on. It is necessary to confirm the control condition of the oxidizing agent provided for improving the quality of the oxide film. To solve this problem, the temperature and concentration of gases can be measured simultaneously by TDLAS[1]. Developed this technique can be measured for 2-dimensional distributions by CT-TDLAS[2]. It is the most important technique for measuring the distributions of temperature and concentration in target gases. However, real flame or supplying gases are not uniform. In this study, suggest a 3-dimensional measurement of irregular flow or exhaust gases. Phantom data sets have been generated by the use of Gaussian distribution for expected temperature and concentration in target gases. The data of the HITRAN database in which the light spectra of the H_2O and the thermo-dynamical properties are listed were used for the numerical test. It is proposed a new 3-dimensional CT-TDLAS measurement to consider the 3-dimensional space.

2. Theory and methods

When irradiated with laser light to the measurement target gas, state changes the gas molecules absorb light of certain wavelengths. TDLAS used such kind of properties. It is based on Lambert Beer's law. This method utilizes the intensity ratio of incident light and transmitted light for the laser, such as can be measured the temperature and concentration of target gas. This relationship can be explained as shown in Eq. (1).

$$I_\lambda / I_{\lambda 0} = exp\{-A_\lambda\} = exp\left\{-\sum_i \left(n_i L \sum_j S_{i,j}(T) G_{Vi,j} \right)\right\} \tag{1}$$

Here, $I_{\lambda 0}$ is the incident light intensity, I_λ is the transmitted light intensity, A_λ is the absorbance, n_i is the number density of species i, L is the path length, $S_{i,j}$ is the temperature dependent absorption line strength of the absorption line j, and $Gv_{i,j}$ is the line broadening function.

Several types CT algorithms to reconstruct data form of the tomography system. In this study used the SMART algorithm[3] for three-dimensional calculate. It can be shown following Eq. (2). It has been used for accelerating the convergence speed for the calculation of a large amount of data.

$$\alpha_{\lambda,i}\left(x,y,z\right)^{k+1}=\alpha_{\lambda,i}\left(x,y,z\right)^{k}\cdot exp\left(\sum_{j=1}^{J}\frac{L_{ij}}{\sum_{i=1}^{I}L_{ij}}\cdot log\frac{A_{\lambda,j}\left(x,y,z\right)}{\sum_{i=1}^{I}\alpha_{\lambda,i}\left(x,y,z\right)\cdot L_{ij}}\right) \quad (2)$$

Here, α is the absorption coefficients.

Performing the iterative calculation which was used for minimizing the differences between the phantom absorbance and the CT reconstruct absorbance using the MSE (Mean Squared Error) equation as shown in Eq. (3).

$$Error=\sum\left\{(A_{\lambda,j})_{theory}-(A_{\lambda,j})_{phantom}\right\}^{2} \quad (3)$$

3. Results and discussion

In this study, three absorption lines located at 1388.139nm (#1), 1388.328nm (#2) and 1388.454nm (#3) have been chosen for the calculation of temperature and concentration of H_2O. By expanding the structure of the existing 2-dimensional measurement cells (each cell: 16-laser paths) to 3-dimensions, a 3-dimensional measurement of the temperature and concentration fields becomes possible using the total 96-laser paths. The 3-dimensional measurement system was designed by stacking five 16-path cells with oblique paths as shown in Fig. 1. Phantom absorption spectra for 3-dimensional measurement were configured using Gaussian distribution. Fig. 2 shows an evaluation for finishing iterative calculations chosen for data reconstruction is based on the MSE (mean square error) which is the error between the phantom data and the reconstructed data at the whole iterative step. Fig. 3 shows a comparison result of the temperature distributions for phantom and CT-TDLAS.

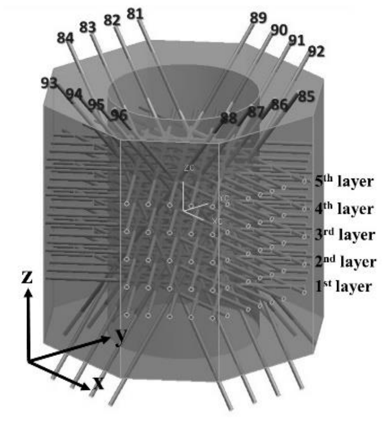


Fig. 1. Schematic of optical 96-paths

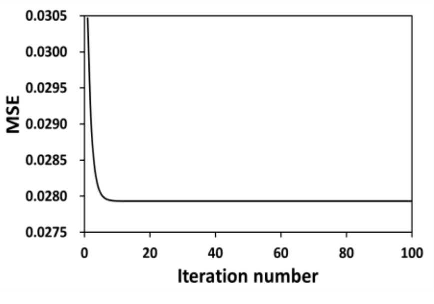
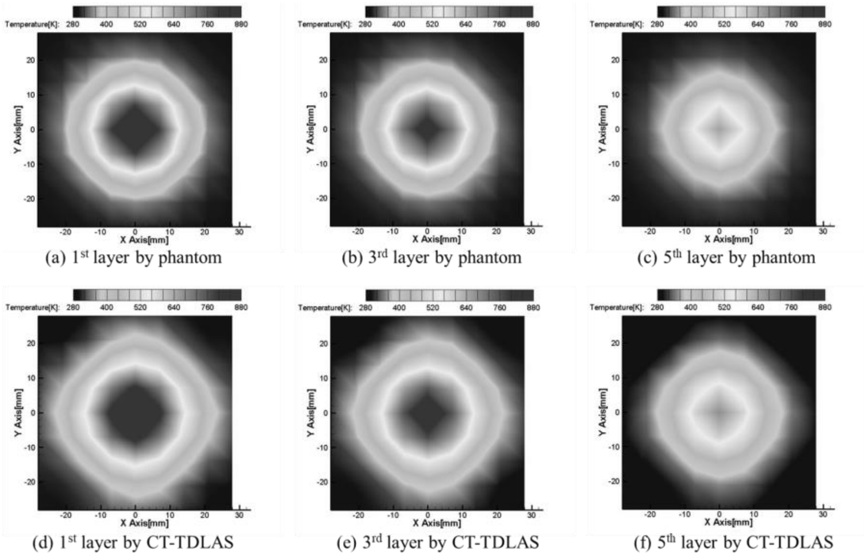


Fig. 2. Total MSE (mean square error) variations for the iteration number



(a) 1st layer by phantom (b) 3rd layer by phantom (c) 5th layer by phantom

(d) 1st layer by CT-TDLAS (e) 3rd layer by CT-TDLAS (f) 5th layer by CT-TDLAS

Fig. 3. Temperature distributions by phantom and CT-TDLAS (1st, 3rd, 5th layer)

4. Conclusion

This study was performed the CT-TDLAS calculation for the three-dimensional phantom measurement space. In order to three-dimensional CT calculation of the phantom H_2O absorption spectra, we adopted to Gaussian distribution to construct the initial temperature and concentration distributions by three-dimensionally. The average relative error of temperature was about 3.2% by using the SMART algorithm in CT-TDLAS calculation. The maximum error was 86.8K. Therefore, can confirmation the supplying gas condition by using three-dimensional CT-TDLAS method. It can be expected for improving the quality of materials manufacturing process.

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