Pulsed UV Light on Au-decorated Carbon Nanotubes Gas Sensor to Determine NO_2 Concentration

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1. SUMMARY:

We show that analysing the transient response of a pulsed UV light-excited carbon nanotube sensor enables the quantification of NO2. Fast Fourier Transform feature extraction coupled to Partial Least Squares models were used. We demonstrate that combining pulsed UV light together with FFT and PLSR analysis, makes possible quantifying NO2 for a CNT sensor operated at room temperature, enabling low power consumption and reduced response time (quantification in just 4 minutes), since it is not mandatory to achieve steady-state or regain a stable baseline for identifying gas concentration (Figure 1).

2. MOTIVATION and RESULTS:

Although CNTs have been widely studied as gas sensors, some challenges still remain unsolved. Measurements employing CNTs at room temperature show important drift problems and poor reproducibility. Moreover, desorption of gas molecules is a big issue[1] (e.g., achieving a stable baseline), increasing the time needed to reliably detect gases. Operated at room temperature and suddenly exposed to NO2, a CNT sensor nay not have reached the steady-state after 8 hours, and baseline recovery under dry air may not be recovered after 40 hours. One alternative is to heat up the sensor surface to desorb gas molecules[2], increasing power-consumption. Another alternative is applying UV light in the recovery phase to desorb the species attached on CNT[3], but this technique does not improve the response time during the adsorption phase.

O. Gonzalez and co-workers[4], reported the use of pulsed UV light on metal oxide gas sensors, obtaining the information to identify the gas concentration from the resistance change (rates) due to the light modulation. Nevertheless, this approach was not useful in our case, not allowing a clear determination of the concentration (see PCA results in Figure 2a). Therefore, we have used a new signal treatment based on PLSR analysis, where the features input to the model are FFT components and observations are the different gas concentrations. A PCA analysis employing FFT components indicates that PC1 relates to concentration (Figure 2b). We generated a training matrix with information from 7 cycles of 300, 500 and 700 ppb of NO2. A PLSR model was obtained from the training matrix, and a cross-validation mechanism was used, by mean of a leave-one-out strategy. This strategy was carried out by taking the information about the three concentrations of a cycle as validation set and the rest of information as training set. This process was repeated 7 times to test the prediction accuracy of all the training matrix.

The method described was successfully implemented for a gas sensor based on CNTs decorated with gold nanoparticles. We found an R-squared value for the calibration model of 0.9464 and for the validation of 0.9219. The RMSE from the calibration model and the validation were 36.8 ppb and 45 ppb, respectively. The power consumption was reduced about 93% respect to the case of heating the same sensor up to 150 ^oC[2].

References:

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FIGURES:

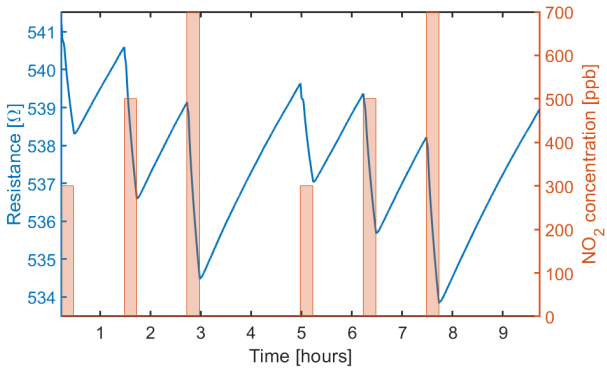

Figure 1: Sensor signal with pulsed UV light and room temperature.

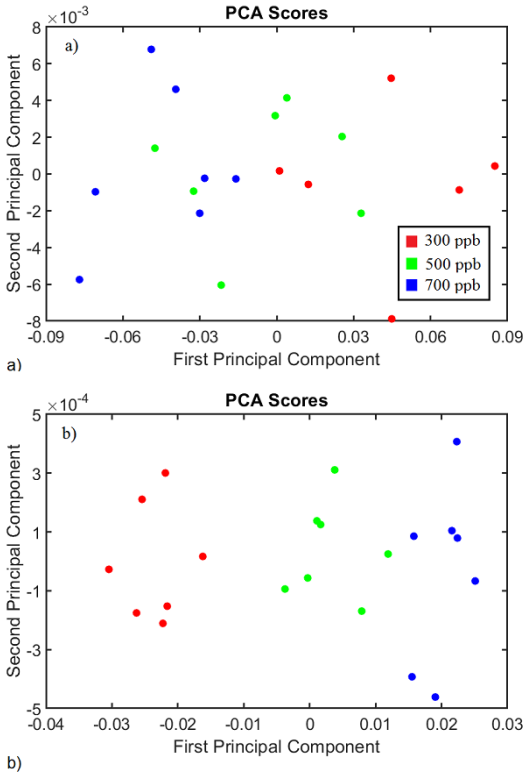

Figure 2: PCA analysis employing rates (a) and FFT components (b).

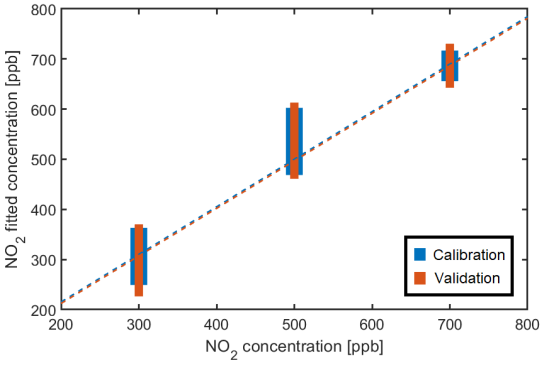

Figure 3. Calibration model and cross-validation of the training matrix.