Determination of Hydrogen Peroxide Concentration in Water-Hydrogen Peroxide Aerosols

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PhD Thesis

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Certificate of Authorship

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of requirements for a degree fully acknowledged within the text.

I certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. I certify that all information sources and literature used are indicated in the thesis.

Signature:____________________________

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List of Publications Produced

A.J. Porkovich, M.D. Arnold, G. Kouzmina, B. Hingley, A.Dowd, M.B. Cortie, *Calorimetric sensor for use in hydrogen peroxide aqueous solutions*, Sensors Letters, **9** (2011) 695-697.

A.J. Porkovich, M.D. Arnold, G. Kouzmina, B. Hingley, M.B. Cortie, *Calorimetric Sensor for* H_2O_2/H_2O *Mist Streams*, IEEE Sensors Journal, **12** (2012) 2392-2398.

C.S. Kealley, M.D. Arnold, A. Porkovich, M.B. Cortie, *Sensors based on monochromatic interrogation of a localised surface plasmon resonance*, Sensors and Actuators, B, **148** (2010) 34-40.

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Abstract

This project focuses on the development of methods for evaluating the concentration of hydrogen peroxide in the mist streams used in a new generation of sterilisation technologies. This application presents unique experimental difficulties in that a sensor must be able to measure the concentration of hydrogen peroxide in a mist of droplets, and be able to do so in the concentration range between 30% and 40% (by percentage weight). Three separate methods of analysis were investigated.

A calorimetric sensor was constructed using a resistance temperature detector (RTD), coated with a heterogeneous catalyst, to measure the heat released after hydrogen peroxide is decomposed. Various ways of implementing this scheme were investigated, including immersion into fluid, dipping followed by drying, and using a heated RTD. The sensor was capable of determining concentrations from 0% to 40% (w/w) in both liquid hydrogen peroxide and aerosol hydrogen peroxide mixtures, with at best 4% and 3% (w/w) precision respectively. Surprisingly, the unheated sensor responded to hydrogen peroxide in the mist by undergoing a *decrease* in temperature. The physical phenomena responsible for this were investigated and explained. The heated RTD worked well as a sensor for mist density, however it was unable to determine concentration.

Three kinds of optically-based sensor were explored. It was determined by simulation that localised surface plasmon resonance using gold nanorods was the best way of developing a sensor based on refractive index. However, in the proof-of-concept experiments the gold nanorods were oxidised by hydrogen peroxide, making this sensor scheme unsuitable for this project. Absorbance spectroscopy was more successful, and was performed on two different path lengths of liquid hydrogen peroxide, analysed with a Fabry-Perot mid-infrared spectrometer. The concentration of liquid hydrogen peroxide could be determined in the range 0% to 27% (volume percentage), with best precision of 1% (v/v). To deal with multiple thicknesses of path length, a numerical technique using a matrix was developed to simultaneously determine concentration and thickness. Finally, some preliminary absorbance measurements of water mist were performed, which showed that, while scattering was significant, there is still a possibility of using this technique in an aerosol, to determine some measure of density. However, this last idea was not explored further here due to lack of time.