EFFECT OF ABSORBED WATER ON ACTIVE BIOSENSOR LAYERS

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Presented at the 16th International Coating Science and Technology Symposium,
September 9-12, 2012, Midtown Atlanta, GA[1]

Introduction

Single use biosensors are widely used by diabetics to test their blood glucose values daily. In the active layer of various biosensor strips, an enzyme is immobilized in a water-borne mixture of polymers which is coated on a polymer substrate and dried to produce test strips. Under extreme conditions, when the films are stored at high relative humidity, water is absorbed which causes a degradation of the film. In this work the degradation process is studied and compared to the water absorption process. The goal is to better understand degradation processes in the film in order to improve handling and ease of use for the patients.

Experimental

The impact of storage at high relative humidity of sensor films was evaluated electrochemically. Storage time and relative humidity were varied to determine a threshold above which observable changes in the films take place. Active sensor films were incubated at different water activities in the gas phase for different durations. Constant water activity in the gas phase was achieved by storage in a closed vessel with a reservoir of a saturated salt solution. The vessel was then placed in a temperature controlled incubator. After incubation the impedance of the films was measured immediately. For impedance measurement a drop of sample liquid was applied to the active layer and the measurement sequence was started.

For the simulation of water uptake in active biosensor layers, diffusion coefficients were determined gravimetrically. A detailed description of the equations for the simulation can be found elsewhere [1].

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[1] Unpublished. ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

Results

Incubation of the test strips at high relative humidity led to an increase in real impedance at 1 kHz. This change in real impedance increased with increasing water activity in the gas phase as can be seen in Figure 1. The increase in impedance begins at water activities above 0.63. After incubation at a water activity of a_w = 0.63 no significant changes are observable. At water activities of 0.75 and above changes were seen.

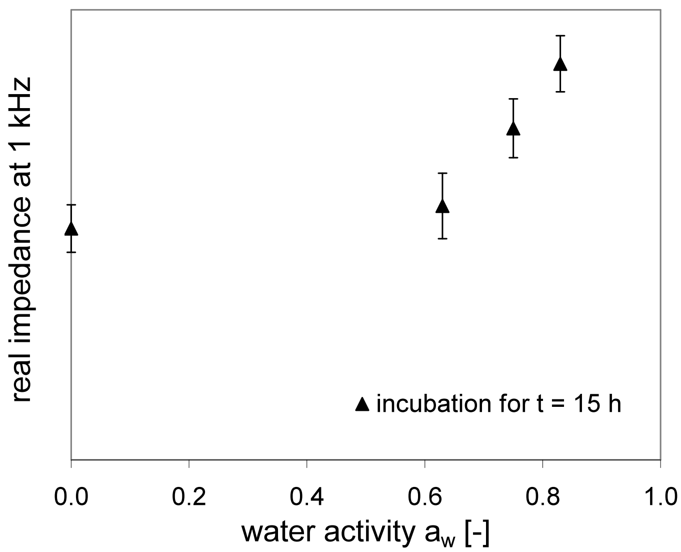

Figure 1: Real impedance at 1 kHz in test strips incubated for 15 h at different water activities in the gas phase.

When test strips were incubated for different durations at a constant water activity of 0.75 the increase in impedance increased with incubation time as shown in Figure 2. After 30 min of incubation only small changes in impedance can be observed. Test strips that were incubated for 15 h at high relative humidity showed the largest changes. A decrease in the slope of the rise indicates that a plateau in impedance will be reached.

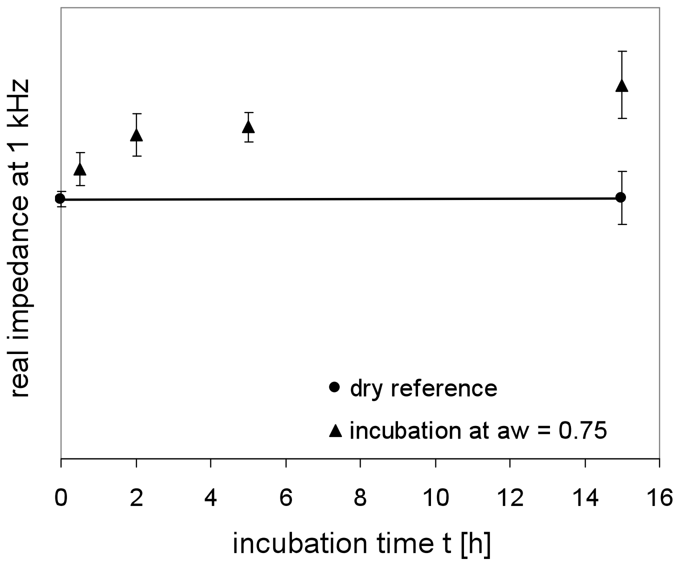

Figure 2: Real impedance at 1 kHz in active layers incubated at a water activity of 0.75 in the gas phase for different durations.

The increase in real impedance relates to water induced changes in the film. Therefore linking the swelling of the film to the impedance changes could help to understand the role of water in the degradation process. As described above, both the amount of water in the film and the exposure time seem to play a role.

For the simulation of water absorption in active layers several parameters of the test strips have to be known: the phase equilibrium and the diffusion coefficient of water in the film. Phase equilibrium and diffusion coefficient are material system properties that have been measured for active formulations very similar to the test strips used in this study. Moreover, the conditions for air flow in the gas phase over the active layer have to be defined. Different model configuration for air flow in the gas phase were tested and evaluated such as flow over a flat plate and flow in a channel. A simulation for water absorption into a film for the geometry of flow over a flat plate is shown in Figure 3. It can be seen that after 30 seconds the water has already reached the bottom of the film and that the equilibrium moisture content in the film is reached after 15 minutes.

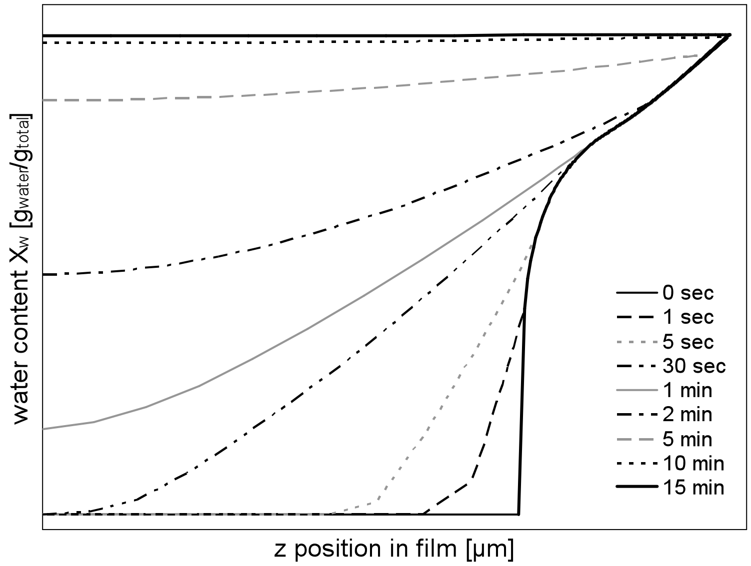

Figure 3: Simulation of the swelling of an active layer at a water activity in the gas phase of a_w = 0.83. The geometry was assumed as a flat plate in laminar flow with an air velocity of 0.1 m/s. Dry film thickness was 10 µm.

The degradation process takes place on a different time scale and is not even finished after 15 h. These findings indicate that changes in the film are governed by a degradation reaction that takes place after water is absorbed. Further work will be necessary to identify the mechanisms of film degradation.

Acknowledgements

The authors would like to thank Roche Diagnostics for financial support of this project.

References

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