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Hydrogel-based pH-sensors

Development and characterization of optical and electrical pH sensors based on stimuli-responsive hydrogels

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Abstract

The ability to measure the chemical parameter pH is of high importance in many areas. With new government regulations and evolving markets, there is a strong motivation for improving such measurements and conducting research on new types of pH sensors and sensor materials. Stimuli-responsive hydrogels (a group of polymers) have attracted a lot of attention in recent decades, due to their ability to be customized to suit many applications. One specific area where they have attracted attention is pH sensor technology.

Two stimuli-responsive hydrogels are used in this thesis. One is a non-toxic hydrogel, 1,4-acryl-terminated oligo(β-amino esters) (1,4-AOBAE). Although it was previously used in drug- and DNA- delivery systems, it has not (to my knowledge) been used in a sensor configuration, and thus it is interesting to study. The second hydrogel, 1,3-acryl-terminated oligo(β -amino esters) (1,3-AOBAE), is an improved variant of the first one. This improved hydrogel was synthesized because the original hydrogel crystallizes at room temperature, which meant that it was not optimal for various coating techniques. This hydrogel was characterized and verified for pH responsivity in two sensor configurations: electrical and optical.

Designing a hydrogel for a specific application can be a complex procedure due to the many synthesizing parameters. For example, increasing a hydrogel's mechanical strength by introducing a higher degree of cross linking, leads to a smaller mesh size, which in turn leads to a lower diffusion rate and less solution absorption. The two hydrogels examined in this thesis respond to pH changes by absorbing or desorbing water; this change in the hydrogel's water content also changes its effective refractive index and permittivity. These changes can be measured using optical or electrical sensor systems. Three types of sensor systems were used in this thesis to verify the hydrogel's pH response and to ensure that they are suitable for use in thin-film techniques on various substrates (e.g. glass and plastic).

The experimental results prove that these hydrogels are suitable for use in both electrical and optical sensor configurations. For electrical systems, a pH range of approximately 3-12 was achieved, and for optical, the range was approximately 2-12. These ranges can likely be improved, as the sensor film delaminated from the substrate at low pHs due to adhesion problems and as measurements above 12 were not conducted.

The findings of this thesis could, after more research, have strong implications for the development of improved pH-sensor configurations, especially for medical and healthcare applications and in environmental monitoring.

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