Measuring the Modulus of Hydrated Contact Lenses via Surface Wrinkling

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INTRODUCTION

Hydrogels are soft materials capable of absorbing large quantities of water. Because they possess qualities very similar to those of soft tissues, they have found widespread use in the field of biomaterials with applications ranging from contact lenses to tissue engineering. For contact lenses, increasing demands are being placed on these materials in terms of comfort, extended wear, and oxygen permeability while maintaining optical clarity. Consequently, new formulations are being developed at a rate that out-paces the ability to measure the materials' properties.

One of the most important considerations in the evaluation of hydrogels for biomedical and contact lens applications is the elastic modulus. The elastic modulus relates to several important factors including flexibility, comfort, adhesion, swelling behavior, and the potential for cell proliferation and growth. While current methods for assessing the modulus of hydrogel materials sufficient for quality control, they are not readily adaptable to the latest innovations in contact lens design, such as bifocal or multifocal contact lenses. Thus, there is a critical need for new measurement strategies that provide spatial mapping of the mechanical properties across a contact lens specimen. Furthermore, the ability to measure depth-dependent properties would also be very attractive.

We have developed a metrology[1,2] based on surface wrinkling that provides an accurate measure of the modulus of soft materials such as hydrogels and elastomers. This methodology leverages an elastic instability that occurs upon compression of a stiff sensor film supported by a soft substrate (see Figure 1). The periodicity of the buckling pattern is dependent on the modulus ratio between the film and substrate as well as the thickness of the sensor film:

$$\lambda = 2\pi h \left(\frac{\bar{E}_f}{3\bar{E}_s} \right)^{1/3}$$

where $\bar{E}$ is the plane-strain modulus ($\bar{E} = E/(1-\nu^2)$), ν is Poisson's ratio, h is the thickness of the sensor film, and λ is the wavelength of the instability (subscripts f and s denote the film and substrate, respectively).

In this talk, we will discuss some of the measurement challenges that we have encountered and solutions we have developed for working with soft, hydrated contact lens materials. The accuracy of the measurement platform will be highlighted with respect to within-sample and sample-to-sample variability, humidity, and contact lens formulation. We will also discuss the application of coherent anti-Stokes Raman spectroscopy to profile the water distribution as a function of depth within the hydrogel specimen.

REFERENCES

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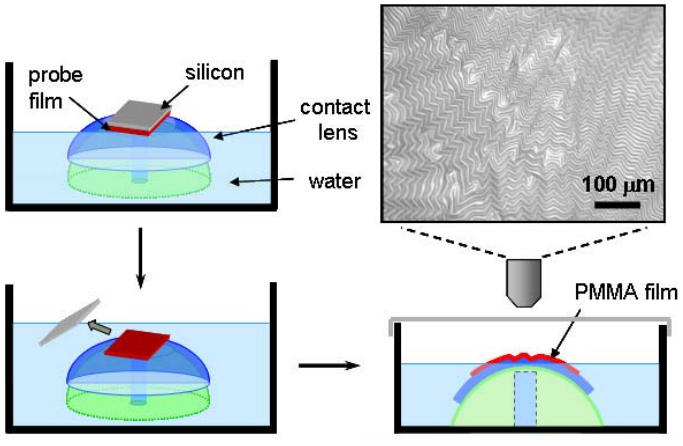

Figure 1. Schematic of experimental geometry for wrinkling of a sensor film (poly(methyl methacrylate) (PMMA)) on a contact lens. Optical microscopy is used to ascertain the wrinkling wavelength.

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