3D TOF-SIMS Characterization of Drug-Loaded Silicone Hydrogel Contact Lenses in the Frozen-Hydrated State

Gregory L. Fisher[(1)]*, Tong Leung[(2)], Doerte Luensmann[(3)], Miriam Heynen[(3)] and Lyndon Jones[(3)]

(1) *Physical Electronics, 18725 Lake Drive East, Chanhassen, MN 55317, USA*
(2) *Dept. of Chemistry, University of Waterloo, 200 University Avenue West, Ontario, N2L 3G1, Canada*
(3) *School of Optometry, University of Waterloo, 200 University Avenue West, Ontario, N2L 3G1, Canada*
*gfisher@phi.com

Visualizing the spatial distribution of a specific molecular agent, or of a chemical moiety, is a fundamental function of TOF-SIMS. Thermal control of certain samples, e.g. hydrated specimens, is required in the process of chemical imaging by TOF-SIMS because evaporation of volatile species from the surface may alter the sample morphology, disturb the surface chemical distribution, and/or modify the 3D chemical distribution. The vacuum environment has a background comprised in part of water vapor; thus, cooling the sample below the temperature required to prevent sublimation of water from the sample surface will produce condensation of water from the vacuum system onto the sample surface. Since TOF-SIMS is inherently surface sensitive, condensed water vapor due to over-cooling will quickly impede the capability to collect useful chemical information. In such instances, the mass spectrum will be dominated by cluster ions of water, either $(H_2O)_nH^+$ or $(H_2O)_nOH^-$ [1]. There is generally an ideal temperature in the range of -80 ^oC to -110 ^oC wherein a balance is obtained between surface sublimation and condensation of water.

The exercise of temperature control over a sample during TOF-SIMS analysis has, to date, virtually eliminated the possibility of sample motion during analysis. That is to say, the complete imaging capability of TOF-SIMS is restricted to the relatively small field-of-view defined by the primary ion gun. In this study, we demonstrate the unique capability of a new sample handling design that provides access to all areas of the sample surface during precise temperature control. This new analytical capability is exhibited by obtaining chemical images from large areas (i.e. > 12 mm^2), as well as depth profiles to approximately 1 μm, of frozen-hydrated samples. The sample set consists of silicone hydrogel contact lenses having a 24% (w/w) water content; one lens is drug-loaded with Ciprofloxacin, an antibacterial agent, and one lens has no drug loading. The sample temperature of the frozen-hydrated hydrogel lenses was precisely controlled at -80 ^oC throughout the duration of the TOF-SIMS analyses as well as during the few minutes of fully automated sample introduction.

The TOF-SIMS mosaic (large area) images of the drug-loaded hydrogel lens reveal that the antibacterial distribution is relatively uniform at the surface. However, depth profile analysis to 1 μm from the surface reveals that the relative concentration of the antibacterial is somewhat reduced at the surface in comparison to the bulk. The depth profile data indicate that a low molecular weight fraction of the hydrogel matrix, predominantly silicone, has evolved to the surface to form an approximately 150 nm thick surface layer. Below the surface layer of low molecular weight silicone the antibacterial distribution appears uniform.

[1] D.M. Cannon, M.L. Pacholski, N. Winograd, and A.G. Ewing, *J. Am. Chem. Soc*. **122** (2000) 603.