Electroless Silver Deposition on PDMS Substrate

Karl Goldsmith¹, Andrew Hillier², Michael Johnson², Russell Mahmood²
¹West Des Moines Valley High School, ²Iowa State University

Surface plasmon resonance (SPR) is a technique used to enhance spectroscopic analysis. SPR works by having the electrons on a thin layer of metal resonate with incoming light (Figure 1). Polarized light is shown on the thin layer which causes the electrons to oscillate. When this oscillation of electrons resonates with the wavelength of incoming light, it creates the plasmon. As molecules interact with the SPR, the detection signal will change in intensity allowing for the kinetics of the chemical interaction to be analyzed. This technique to can be useful in biosensing techniques and spectroscopy.

Once the grating is obtained, the thin-layer of metal needs to be added. Due to the methyl groups on the PDMS, it is a very stable, nonreactive molecule. To coat the PDMS replica with silver, an electroless deposition method was used. Electroless deposition is similar to electroplating but can be done without the need for an external current. It is effective because it can deposit silver on both conductive and nonconductive materials, such as polymers. The goal for this experiment was to create a PDMS replica with a silver nano-layer using Tollens’s reagent, a known electroless method for depositing silver on glass.

Three steps were necessary to create the silver coated PDMS samples: pretreating the polymer, creating the Tollens’s reagent, and silver deposition.

Pretreatment:
Once the PDMS was cured, the samples were pretreated for silver deposition. The samples were rinsed with DI water and acetone. They were then plasma sensitized and soaked in a tin(II) chloride solution. These last steps make the fairly inert polymer prepared for silver deposition.

Creating the Tollens’s Reagent
The Tollens’s reagent is comprised of two parts: the silver solution and the reducing agent. The silver solution was 0.5M AgNO₃ and 0.8M KOH. The reaction product silver nitrate was then reacted with enough NH₃ to create a diamine silver complex. The reducing agent was a solution of 0.5M dextrose.

Silver Deposition:
To deposit the silver, the silver solution and reducing agent were mixed at a ratio of 50 ml to 15 ml. The pretreated PDMS sample was placed in the solution for 10-60 seconds. During this time, the silver replaced the tin on the PDMS which created nucleation points of silver and enabled the silver to coat the surface of the PDMS.

The samples were analyzed using optical microscopy and scanning electron microscopy. The top images show SEM analysis of a PDMS sample on the edge and in the middle. The bottom images show optical images of samples at ten second intervals of silver deposition.

Based on the results of these experiments, silver was successfully deposited on the PDMS. The pre-treatment with plasma and tin (II) chloride sensitizing worked with the Tollens’s reagent to apply a thin layer of silver on the sample. By comparing the samples to standard values, it was determined that the silver was deposited at a rate of 2.7 nm/sec following nucleation. Optimal thickness of silver for an SPR signal is 50 to 100 nm thus requiring a minimum of 33 seconds of deposition. The optical microscope and SEM images show that the sample was coated. Based on the SEM images, there remains impurities on the sample after deposition. The SEM image of the edge of the sample shows that the silver may not adhere well to the PDMS. An SPR peak was shown at 1400 nm and displayed the characteristic shift as the sample was rotated. While the sample was coated with silver, more work should be done to optimize the process. Further work should be done to improve the adhesion of the silver to the PDMS as well as optimizing the SPR signal.

REFERENCES

ACKNOWLEDGEMENT
I would like to thank Dr. Andrew Hillier for allowing me to work in his laboratories. I would also like to thank Michael Johnson and Russell Mahmood for working with me in the design, implementation, and analysis of these experiments. I would like to thank the CBiRC RET program for giving me this opportunity to work in a professional research setting.

The material presented here is based upon work supported by the National Science Foundation under Award No. EEC-0813570 and EEC-1406296. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.