Investigating the Formation of Polymeric Sculptured Thin Films as a Functional Template for Collagen Growth and Attachment

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Abstract:

The primary focus of this project was to form polymeric Sculptured Thin Films (STFs). The vaporization of parylene or poly-para-xylylene and the radio frequency (rf) sputtering of Teflon® or polytetrafluoroethylene (PTFE) were explored. A motion control system was designed to provide two axis control of the substrate. Chiral parylene STFs were successfully deposited. PTFE films were unsuccessfully deposited.

Introduction:

Sculptured Thin Films (STFs) are deposited by glancing angle deposition, typically at 75° or more. Directional flux introduces shadowing effects that force growth in a highly oriented manner. The film grows in the direction of the flux and can be manipulated into columnar, chiral, chevron, or other engineered growth patterns. STFs have been shown to have an abundance of properties that can be engineered to precise specifications.

The goal of this project was to produce polymeric STFs to be used to enhance the attachment of collagen. However, polymeric STF deposition has not been found in the literature. Polymer evaporation and sputtering techniques require some form of polymerization to occur before the vapor species' mobility is lost. Hence, the structure of some polymers will not allow vapor deposition. STFs have a controllable porosity that gives a large surface area for attachment. Larger surface area has been shown to enhance cell attachment [1]. Collagen attached to these films would provide a biocompatible material for medical implants and biological sensors. Teflon® or polytetrafluoroethylene (PTFE) has been successfully sputtered [2] and was chosen as a STF candidate. Parylene was chosen because a deposition system was already available for use and parylene has been shown to be good bio-active material.

Experimental Procedures:

A motion control device was built to enable deposition at various angles with substrate rotation. The stage assembly was designed to be used inside any vacuum system and controlled in real time with a windows interface. The system can operate at 10^{-7} torr and 155°C internal temperature. Conventional parylene deposition systems use non-directional flux to achieve conformal coatings. For STF deposition, a nozzle was constructed to provide directional flux. Deposition time was measured from when the vaporization temperature reached 150°C to when the system was manually shut-down. Parylene depositions were done for five, ten, and fifteen minutes with rotation speeds of 0.167 and 0.025 rotations per second at 80° from the normal of the flux. Two depositions were done perpendicular to the vapor flux as control samples. Depositions were done on Corning Glass and also on silicon for SEM microscopy. In an attempt to maintain the same vapor pressure during each deposition, five grams of the parylene C dimer were inserted into the vaporizer for each deposition.

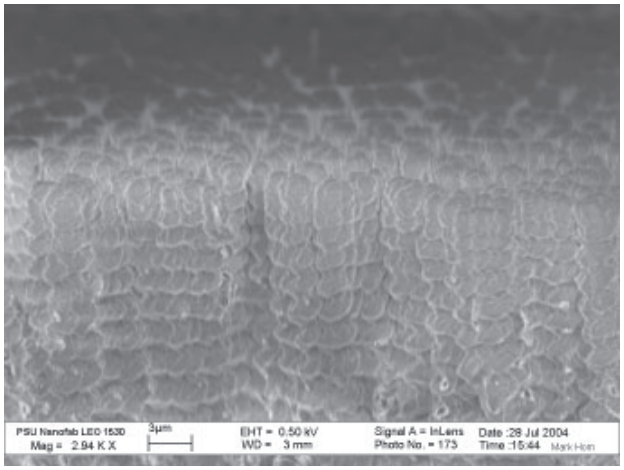

Figure 1: Chiral parylene sculptured thin film (0.025 rps).

Sputtering PTFE was attempted during the end of the project. A PTFE target, one eighth inch thick, was constructed for a two inch sputtering gun. Five depositions were done at varying pressures and powers in order to find a deposition rate.

Results:

The parylene depositions that were done at a glancing angle turned a frosted white color to the naked eye. The depositions done at normal incidence were transparent. Deposition thickness varied from 15-30 μm showing no apparent dependence on deposition time. The microscopy results showed a chiral structure for a ten minute deposition on a silicon substrate rotating at 0.025 rotations per second, as seen in Figure 1. The results show fifteen turns at a thickness of about 30 μm. This gives the chiral columns a period of ~ 2 μm per turn. An interesting result was seen on the same sample. A section of the film had delaminated from the substrate revealing a pin-hole free bottom surface, as seen in Figure 2. The results for substrates rotating at 0.167 rps showed a more complex structure, as can be seen in Figure 3.

PTFE rf sputtering did not give any film as measured by profilometry. A bright argon plasma was formed and upon removing the target a faint erosion track was seen.

Discussion:

The parylene deposition system did not allow enough user control to form the engineered films that were sought. The pressure could not be controlled. Residual vapor in the system was deposited after the vaporizer was shutdown. This may explain the discrepancy in the deposition rate. The results show that polymeric STFs can be formed from PVD processes. The chiral films that were formed showed a continuous under layer. This layer would provide the same barrier from gas and moisture that a conventional parylene film would and could be important in implantable device applications. The films deposited at 0.167 rps showed a structure containing a weaving of parylene strands underneath columns, seen in Figure 2. These films were unexpected but may provide an increased surface area for collagen attachment. PTFE sputtered films were too thin to measure with profilometry. However, the erosion track suggests that PTFE was sputtered and a longer deposition time was needed. No other PTFE depositions were attempted and experiments evaluating collagen attachment were not done due to time constraints.

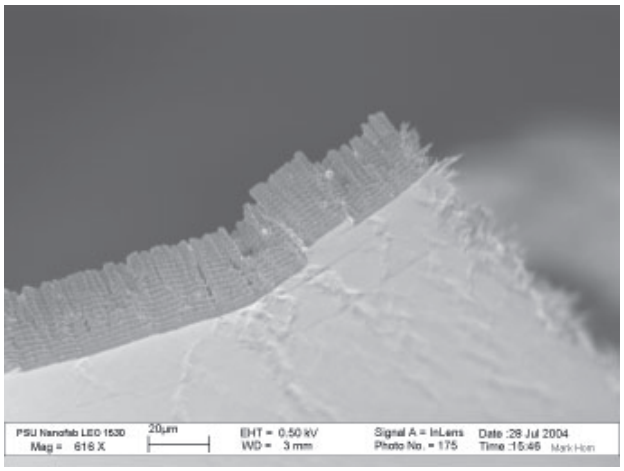

Figure 2: Continuous under layer of parylene STF (0.025 rps).

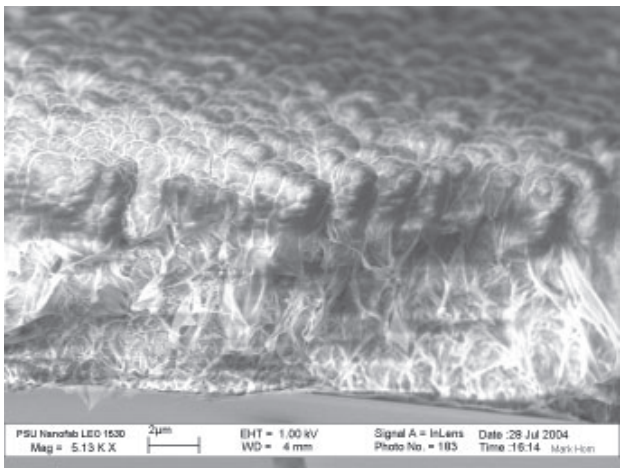

Figure 3: Parylene strands underneath columns (0.167 rps).

Conclusions:

1. Polymeric STFs can be made from PVD processes and more polymers need to be investigated to determine the films usefulness.
2. Parylene can form STFs but a system made to produce a controlled directional flux needs to be used to attain the engineering control necessary for more in depth investigations.
3. Current parylene films need to be tested for collagen attachment and growth.
4. Attempts to form sputtered PTFE STFs will need to be done with longer deposition times or by increasing deposition rates by increasing rf power or target size.

References:

[1] T.A. Desai, J. Deutsch, D. Motlagh, W. Tan, and B Russell, Biomedical Microdevices 2:2, 123-129, 1999.

[2] G.A. Hishmeh, T.L. Barr, A. Aklyarov, and S. Hardcastle, J. Vac. Sci. Technol. A, Vol. 14, No. 3, 1330-1338 May/June 1996.