12-24-2022

Rolling Up Single Layer Polymer

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Fall 2022 MEMS Independent Study

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I.S. Date: Fall 2022

Report Submission Date: Friday, December 23, 2022

I hereby certify that the lab report herein is my original academic work, completed in accordance with the McKelvey School of Engineering and Student academic integrity policies, and submitted to fulfill the requirements of this assignment:

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INTRODUCTION

This report collects two methods of rolling up a single layer of polymer and four experiment procedures based on these two methods. For the first method, the thermal expansion coefficient is the main point of detaching the polymer layer from other layers; however, for the second method, the swelling occurs with the help of metal, and the detachment of layers is reached by using a solvent that can solve the metal. Three of four experiments were done during the semester, and the experience of failure will help with future experiment procedure making.

METHODS

Method 1: The idea comes from the paper: Highly Symmetric and Extremely Compact Multiple Winding Microtubes by a Dry Rolling Mechanism [1]

In this paper, the rolling occurs because of the difference in thermal expansion. Figure 1 shows the model and two mechanisms based on this model. In this model, there are three layers, Si/SiO2, Fluorocarbon polymer , and strained layers. The first mechanism shows that when the adhesion between the substrate (Si/SiO2) and Fluorocarbon polymer is larger than the adhesion between the substrate and the strained layers, the strained layers roll up independently. Otherwise, the Fluorocarbon polymer layer and the stained layer will roll up together, which is the second mechanism.

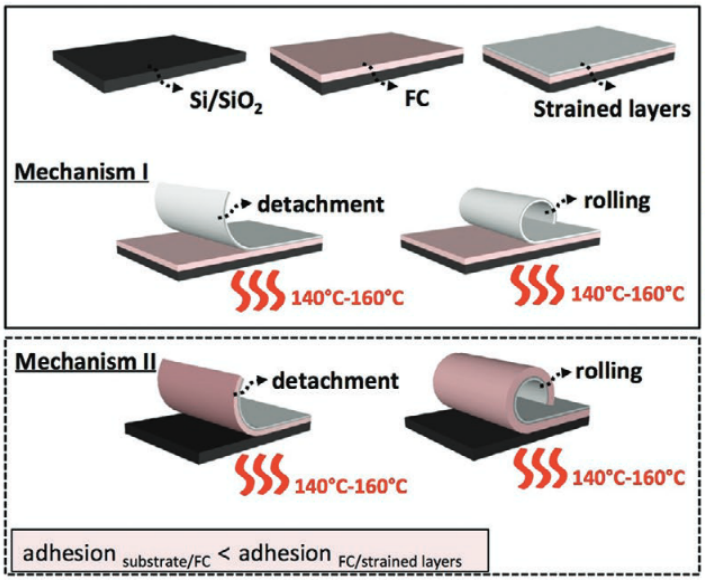

Figure 1 Two mechanisms of the rolling up model

This model can be changed to fit the goal of rolling up one layer of polymer. In the experiment, the top layer was decided to be a polymer, so the polymer itself can be rolled up when the adhesion between the substrate and the middle layer is larger than the adhesion between the middle layer and the polymer. The thermal expansion coefficient of several target materials that the lab can provide is provided in Table 1. The thermal coefficient of PDMS is larger than that of Fluorocarbon polymer, which indicates that PDMS is a good material to use.

Table 1 Thermal expansion Coefficient of several materials.

Material	Thermal expansion Coefficient ($m/°C^{-1}$)	Note
pv3d3	unknown	The thermal expansion coefficient can be readily computed from the thickness–temperature plot's slope using thermal ellipsometry.
PMMA	$7.4 * 10^{-5}$	Reference [2]
PDMS	$3.1 * 10^{-4}$	The material is stable below is 150 °C
Fluorocarbon polymer (PTFE)	$1.24 * 10^{-4}$	Thickness increases, thermal expansion coefficient decreases [3]

Fluorocarbon polymer (PTFE) has a very interesting property: increasing the material's thickness decreases the thermal expansion coefficient [3]. The rolling speed is also related to the thermal expansion coefficient; as the difference between the thermal expansion of FC and PDMS increases, the rolling speed increases. By combining these two features, the rolling speed can be controlled by the thickness of the Fluorocarbon polymer.

Three different experiment processes based on the rolling principle are provided below:

Experiment 1:

1. Put PTFE film (thickness = ⅛’’) on flat water
2. Prepare PDMS 10g:1g

3. Pour PDMS onto PTFE
4. Leave it overnight for curing
5. The next day, anneal at 160C degree

Experiment 2:

1. PDMS 6g:0.6g
2. Spin coat 3000 rpm for 2 minutes
3. Dry at the room temperature
4. Next day, anneal at 160C degree

Experiment 3:

1. Spin coat PMMA on SiO2 with 3000 room for 2 minutes and then 180C degree for 2 minutes
2. Anneal at 180C degree for 2 minutes
3. Spin coat PDMS on PMMA with 3000 rpm for 2 minutes
4. Dry at room temperature overnight

Method 2: The idea comes from the paper: Fabrication of Metallic Microtubes Using Self-Rolled Polymer Tubes as Templates[4]

In this paper, the material used is PS(Polystyrene)/P4VP(Poly(4-vinyl pyridine)) and metal(Au/Ti). The swell occurs by putting the P4VP in DBSA solution, a dodecylbenzene sulfonic acid. There are a few steps mentioned in this paper. First, a bilayer polymer of PS and P4VP is deposited on the silicon wafer, and the bilayer is cross-linked by UV radiation. Then the thin film is deposited on the bilayer, and several scratches are made using a sharp blade. After immersing the sample in DBSA, Pyrolyzed the sample at 500 C for 3h in an oven to remove the polymers and the metallic tube forms.

Drawing on this article's experimental scheme, an experiment setup, and procedure based on the

PDMS is provided below.

Experiment 4:

1. A bilayer polymer of (Polymer 1) and PDMS(PDMS can swell in several solutions such as diethyl ether, DCM, and xylene) is deposited on the silicon wafer.(Dip coater)
2. Cross-linked the bilayer by UV radiation and make scratches by using a sharp blade
3. The rolling up may exist if the sample is immersed in diethyl ether, DCM, and xylene.
4. Use the way of de-cross-linked of PDMS to dissolve the polymer 1. After that, only the PDMS tube will be kept.

RESULTS & FUTURE STEPS

The method section describes four different experimental procedures based on two different ideas. Experiments 1, 2, and 3 are done during the semester. Unfortunately, these three experiments all failed. Experiment 4 is still scheduled.

Based on the thermal expansion coefficient principle, the experiment still has some problems. The PTFE we bought on line has a thickness of ⅛''. However, the thickness-dependent conclusion was found during the thickness range from 96nm to 1154 nm. Also, the website does not provide the initial numerical data of the thermal expansion coefficient of the material we bought. In the future, it might be helpful if we can use much thinner PTFE and do the numerical calculation of the thermal expansion coefficient under different thicknesses and temperatures based on the initial value of the thermal expansion coefficient.

References

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