National Institute for Nano Engineering

SAND2011-4956C

Nanoimprinting and Characterization of Thermoresponsive Shape Memory Polymer

Jean Fakhoury[1,2], Chip Steinhaus[1], Ray Friddle[1], John Zhang[2], and Jack Skinner[1]

[1]Sandia National Laboratories, Livermore, CA, [2]Department of Biomedical Engineering, University of Texas at Austin

MOTIVATION

Shape memory polymers (SMP) are able to "remember" their original shape even if immobilized in temporary secondary shapes. Compared to shape memory alloys, SMPs possess several advantages such as higher elastic deformations, low cost, tunable stiffness, and ease of processing. In addition, many SMPs can be made biocompatible and biodegradable making them amenable for biomedical applications such as drug delivery and implants. We present a simple method to create nanopatterns on SMPs and characterize their intrinsic thermoresponsive shape memory effects.

SHAPE MEMORY MATERIAL

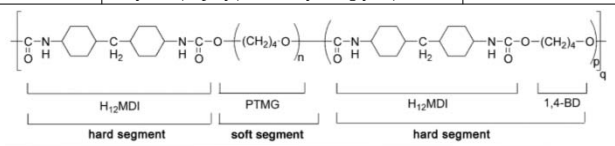
Tecoflex EG-72D (Lubrizol, USA)

- Di-block co-polymer poly(ether urethane)
- Two segments drive shape memory effect

Tecoflex Film Preparation

- Dissolve in N-Methyl-2-pyrrolidone (NMP) using hot bath (65°C) with sonication
- Spin cast polymer solution on wafer
- Post-spin bake (PSB) using hotplate

Segment	Composition	Glass Transition Temperature
Frozen (hard) Segments	H12MDI/1,4-BD [methylene bis(p-cyclohexyl isocyanate) / 1,4-butanediol]	T_{trans} = 74°C
Reversible switching (soft) Segment	H12MDI/PTMG [methylene bis(p-cyclohexyl isocyanate) / poly(tetramethylene glycol)]	T_{perm} = 120 - 140°C

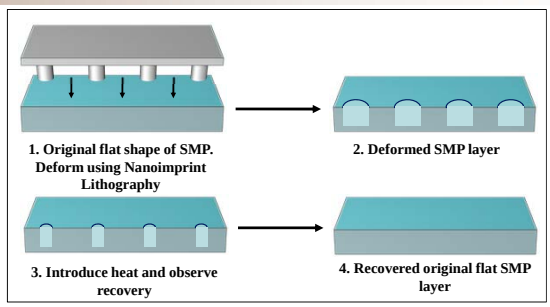


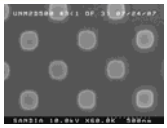
Nanoimprint Lithography

- 10% (w/w) Tecoflex in NMP spun at 1500 rpm for 10sec with 200°C PSB for 2 min
- NIL done using Nanonex 2000
- Mold consisted of posts with 200nm diameter and 500nm pitch

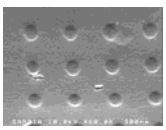
Process:

- Surface dimpled and recovery observed
- Imprint pressures used: 50, 100, 150 and 200 psi at 80˚C for 2min. Next, pressure held until cooled to 40˚C
- Recovery done on hotplate at 80˚C for 2min





SEM of mold



SEM of dimpled SMP layer

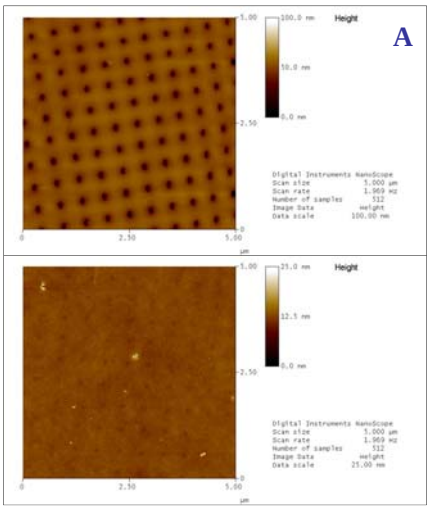
CHARACTERIZATION

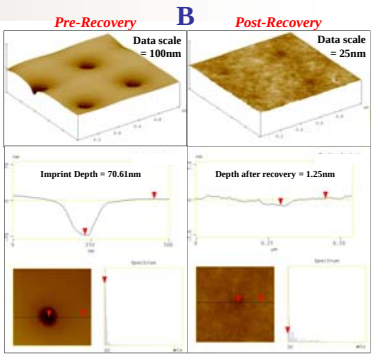
Shape memory effect was characterized using AFM

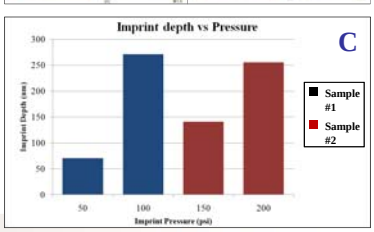
A – Top view of imprinted polymer before and after recovery. In images showing recovered polymer, can barely see where nanowells use to be.

B – 3D view of polymer before and after recovery (top pair). Sectional view of a single nanowell showing depth of the hole before and after recovery (bottom pair). Note difference in data scale.

C – Bar graph showing imprint depth with respect to imprint pressure used. Data shown is of 2 samples . Indeed, depth increases with pressure.







SUMMARY AND CONCLUSIONS

These results show that the integration of SMP materials, such as Tecoflex EG-72D, with NIL is feasible and easily realizable, and can be used to fabricate tunable nanostructures for a variety of potential applications in plasmonic sensing, fluid pumping, and drug delivery. Future experiments will involve the use of AFM to further understand the mechanical properties of Tecoflex.

Sandia is a multiprogram laboratory operated by Sandia Corporation a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000

Sandia National Laboratories