Simulation on the Drying of a Miconeedle Patch

Chung-Min Hsieh*, Ping-Yao Wu and Ta-Jo Liu
Dept. of Chemical Engineering
National Tsing Hua University, 300, Taiwan
Email : luke11840@yahoo.com.tw
Telephone : +886-989-507-804
*Speaker

Abstract

A microneedle patch is a new approach for painless drug delivery. It is mainly fabricated by filling polymer solutions into micro-scaled cavities and subsequently solidified by drying. The geometry of the microneedle cavities and the drying conditions will influence the solidification process. In this project, we focus on analyzing the drying process of microneedle forming.

A polyvinyl alcohol (PVA) solution was filled into a PDMS mold, which consists of numerous conical cavities with 600 micron-depth and 300 micron in diameter. The effects of four variables, i.e., solvent concentration, back-side film thickness, bottom temperature and viscosity, on making microneedle were examined. Figure 1 indicates if the solvent concentration is fixed, changing the film thickness will cause different drying behaviors. If the film thickness is too low, a void appears on the bottom of the microneedle. A visualization device was built up to observe the drying process, the set-up is shown in Figure 2. Figure 3 shows that microneedle and PDMS mold have some shrinking problems, which may be caused by the drying-induced stress.

After determining a quality window mainly based on the experimental study, we developed a mathematical model for describing the drying behavior of PVA solutions filled into the micro cavities inside the window. The model includes the moving interface with coupled heat and mass transfers between the interface and the ambient environment. Vrentas-Duda free-volume theory was used for predicting the concentration and temperature dependency of mutual-diffusion coefficients. This model was solved by the finite element method. The validity of the model was confirmed by comparing the predictions with the drying data as shown in Figures 4-6. It was found the differences were less than 10%. The results indicate that the

microneedle patch can be solidified within one hour by heating the PDMS mold at 100℃. Based on this understanding, we can fabricate microneedle patches more efficiently.

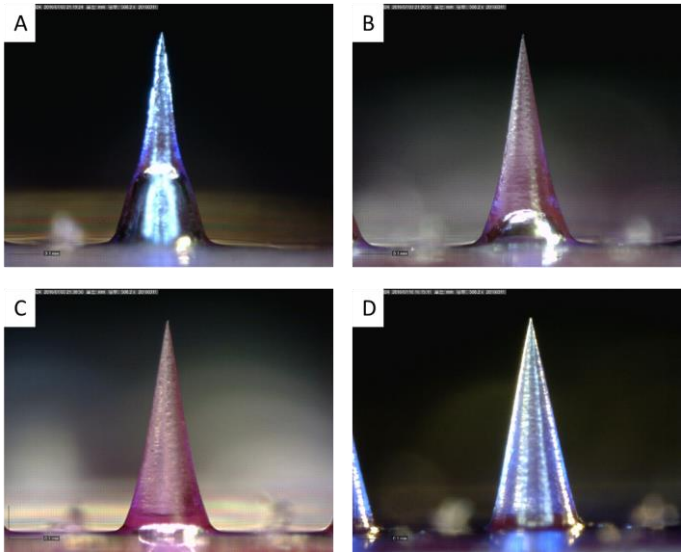

Figure 1 – Observation on the void owing to different film thickness.
(A) 400 um (B) 700um (C) 900 um (D) 1200 um

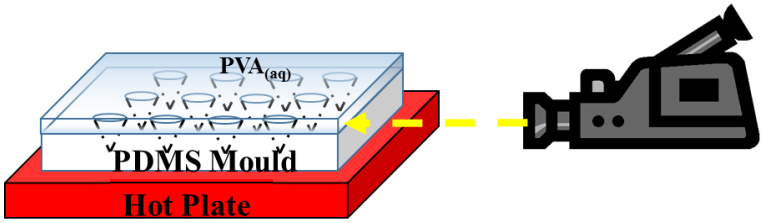

Figure 2 – Visualization device

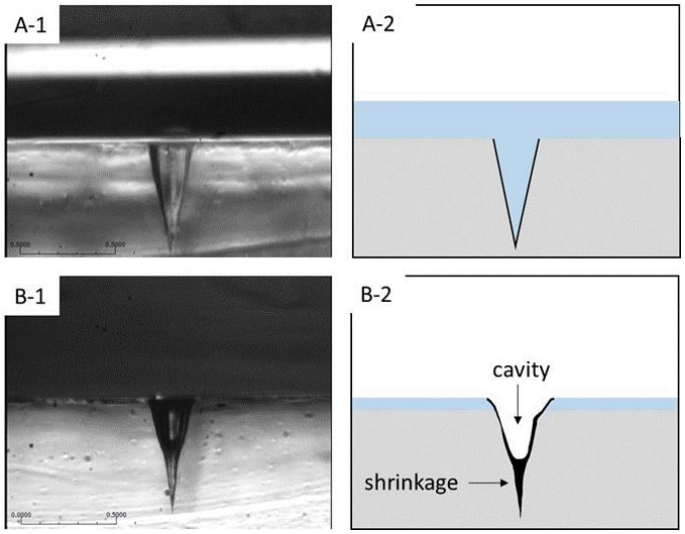

Figure 3 – A void and shrinkage during the drying process
(A-1) Observation on drying at the initial stage
(A-2) Illustration on drying at the initial stage
(B-1) Observation on drying at the final stage

(B-2) Illustration on drying at the final stage

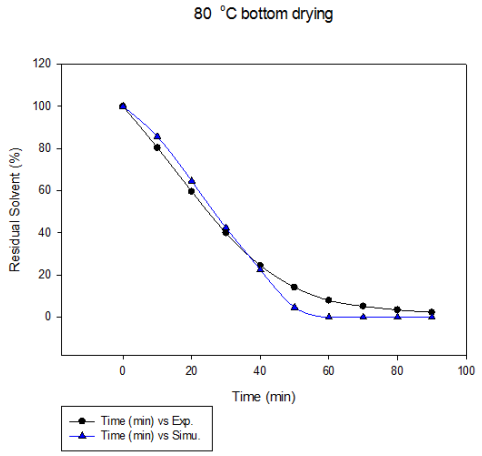

Figure 4 – Residual solvent percentage at 80℃

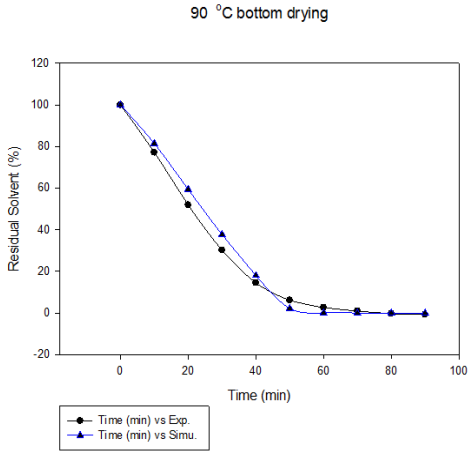

Figure 5 – Residual solvent percentage at 90℃

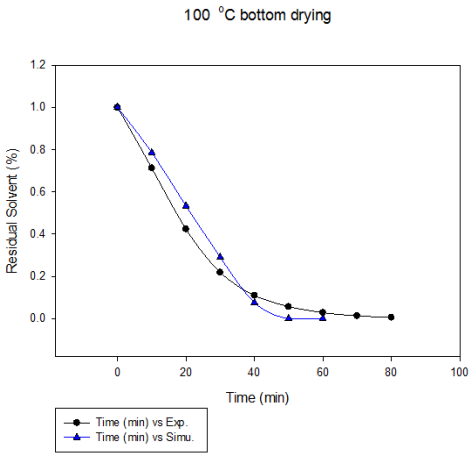

Figure 6 – Residual solvent percentage at 100℃

Keywords: Drying, Microneedle, Modeling, Drug Delivery