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Investigation of a Self-directing Liquid Holder with Computational Fluid Dynamics

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Keywords: liquid holder, capillary force, computational fluid dynamics, diffuser, nozzle, drug delivery.

The current research is to develop a self-contained drug delivery device, which is composed of an actuator and a liquid holder. The actuator basically triggers the drug release by applying appropriate electrical signals [1]. Different from most of the other drug delivery devices which are usually supplied by an externally independent drug reservoir, our proposed drug delivery device will carry all the required drug volume inside the device, therefore the liquid holder is an essential and important part of the device. A proper design of the liquid holder is required to ensure the good performance of the drug delivery device.

The device will work under an inconsistent environment when it is moving inside the human body, a small change in its position may cause a difference in the internal fluid system. These changes could be very critical for the microfluidic system. To obtain a stable and reliable drug release under changeable working conditions, some special requirements must be met when designing the liquid holder. First of all, the liquid holder should be able to hold the liquid all the time no matter what the orientation of the device. On the other hand, a minimum dead volume is always desirable in any drug delivery device. The liquid holder should have a good self-directing ability to supply the drug into the working channel without extra power. The proposed actuator works in a vibration mode, and a reverse flow may occur under the periodic vibration. In the liquid supply direction, a least flow resistance is expected, while in the opposite direction, a large flow resistance is more desired to reduce the reverse flow.

The flow-directing properties of diffuser elements have been well investigated and applied in the design of valve-less pump [2]. The diffuser element is used as the inlet of the pump to direct the liquid flow from the reservoir to the pumping channel. The flow loss at each transient geometric region of the diffuser element varies by different fluid flow directions. In our design of the liquid holder, we will use capillary force to hold the liquid. Another objective of the liquid holder is to minimize the flow resistance in the liquid supply direction, and maximize the pressure loss in the reverse direction, thus the flow-directing properties of the possible three structures: diffuser element, nozzle element, and tube element are studied with respect to their flow loss coefficients in both
liquid supply direction and reverse direction. The analytical study is based on the existing experimental results on some macroscopic devices, to verify the design for the micro devices and the computational fluid dynamics (CFD) in ANSYS-Flotran which applies an Arbitrary-Lagrangian-Eulerian (ALE) scheme is used to simulate flow rate and supply efficiency of each design.

Both the analytical analysis and CFD analysis show that the nozzle element will provide a better flow-directing capability and higher supply efficiency. Some simple experiments using a pipette have been done to further confirm the above conclusions.

References