

THREAD AS A PRECISE SAMPLING AND DELIVERY PLATFORM FOR IMPLANTABLE OR INGESTIBLE APPLICATIONS

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ABSTRACT

A precise-yet-passive liquid sampling and delivery device that can be implanted or ingested has the potential to revolutionize diagnostics and drug delivery. We propose natural capillary action in highly structured hydrophilic threads as a precise liquid volume measuring device with nano-liter resolution. Consequently, the threads were used to accurately calibrate small liquid handling pipettes with working range from 0.2 – 5 μ L. We also demonstrate delivery of fine drug dosage delivery using threads in-vitro where different length of the thread translates to different drug dosage.

KEYWORDS: Thread, Drug delivery, Liquid Sampling, Biomedical Devices, Eatable Devices

INTRODUCTION

A hydrophilic thread uptakes liquid samples naturally [1] and a thin film of liquid evolves on the thread [2]. Our original concept is to translate the wetted length of the thread to the uptake volume of the liquid. We show that this depends on the well-organized structure and uniformity along its length that allows for a more uniform and homogeneous wetting along the length of the thread substrate [3].

Numerical simulations were performed to evaluate the wetting behavior on a uniform thread. Results presented in Fig.1 shows that for a thread with a constant diameter along its length, the thickness of the liquid film created on the thread remains constant regardless of liquid sample size (Fig.1a). As a result, a specific length of the thread always contains a well-defined volume of the liquid. Different types of threads Nylon, Polyester and Cotton threads (all naturally hydrophilic) were investigated for their liquid handling capability. SEM images show that Nylon thread with very uniform structure along the thread may provide uniform capillary action for precise wetting (Fig.1b). Polyester thread with similar uniform structure but occasional defects is expected to be less precise. Cotton threads have a highly non-uniform structure is expected to be less precise. Nylon, Polyester and Cotton threads were each examined for the length, density and the amount of the liquid on the thread.

These measurements were performed by choosing 10 samples of each thread with different lengths. Initially the dry weight and length of each sample was measured. Then the sample thread was soaked in pure water and weighed afterwards (Fig.2). To evaluate the amount of water that certain length of the thread can carry, the dry weight was subtracted from the wet weight and divided by the length of the thread. These measurements (standard deviations) confirm the non-uniformity of the cotton thread structure as the standard deviation is much higher compared to the Nylon and Polyester threads (Fig.2).

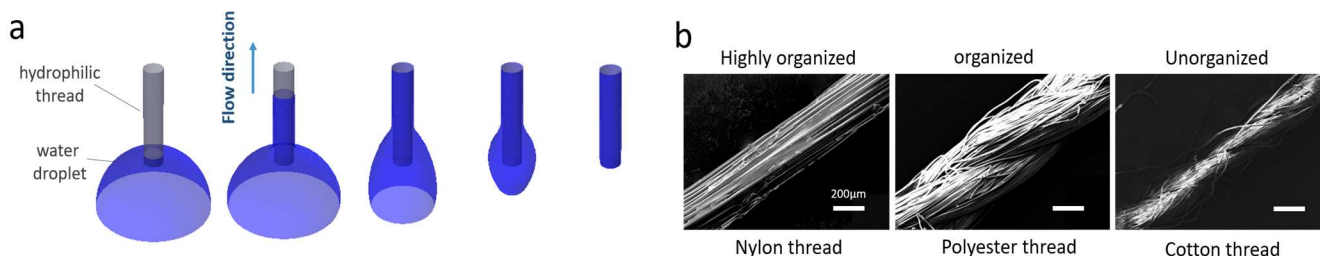


Figure 1: 3D numerical simulation of water uptake on a thread substrate through capillary action, b) SEM images of three different thread types and their structure

Evaporation affects the wetted length of the thread. A tube was used to control the evaporation and increased the traveling length of the liquid on the thread. Figure 2c shows that evaporation can be significantly reduced at room temperature by tubing the thread (Fig.2). This could have been achieved by polymer coating of the thread as

well. Finally, we characterized the wetted length of the Nylon thread to find a translation of the amount of the sample to the wetted length of the nylon thread. The thread precisely follows a linear trend (Fig.2). Figure 4 can be used to find the volume of a sample loaded on the thread or to translate the length of the thread to initial volume of the liquid sample.

We use these results to propose the use of passive thread as a precise drug delivery device. Cresol red dye was used as a drug model and polystyrene thread was used as substrate. The thread was soaked into the solution 1mg/ml of the dye in pure water (similar to sampling procedure) and air dried. Then, drug release was performed on different length of the thread (Fig.3). We observed that almost all the drug was released from the thread in 20 min and the thread color was apparently white after 60 min release test. Linear correlation was observed between the mass of the released drug and the length of the thread used in the experiment (Fig.3d).

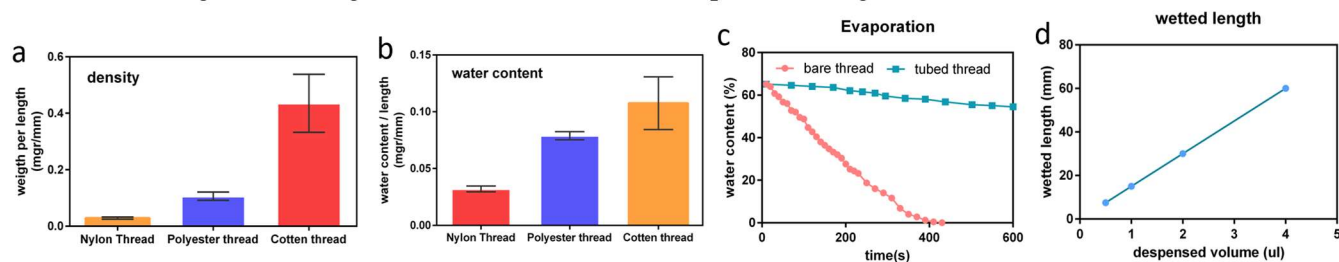


Figure 2: a) Density of each thread and b) weight of the water absorbed by the thread per length for Nylon, Polyester and Cotton threads, c) Evaporation rate of water content of a wet thread at room temperature. d) showing the translation of the length of the thread to initial sample loaded on the thread.

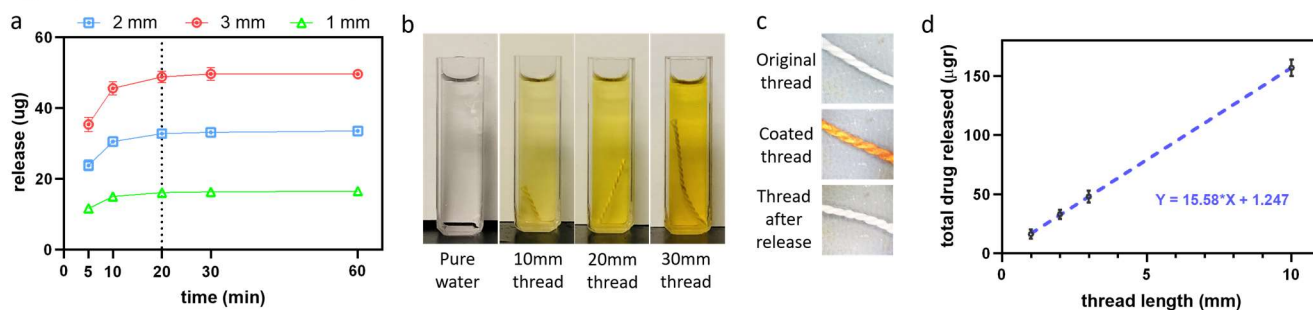


Figure 3: a) Release profile of cresol red dye (drug model) from threads of different length polystyrene thread, b) qualitative assessment of total drug released for different length, c) color of thread before coating, after coating and after drug release test, d) correlation between total drug released and different length of the thread.

CONCLUSION

Here, we have shown the possibility of thread as an accurate measuring device for liquid sampling and as a precise drug dosing delivery platforms. This study shows that thread with fine structures in fact present a highly linear correlation both for amount of liquid they can handle and amount of drug/solute content they carry per their length. Overall, this study sets ground for the development of implantable or ingestible thread-based biomedical devices for sampling, sensing or drug delivery applications.

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