Observations on Inkjet Cartridge Parameters for Biomaterial Deposition

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Statement of Purpose: HP 500 thermal inkjet printers allow a flexible means to deposit biomaterials and cellular components [1]. In our quest to extend the flexibility of this deposition approach we have identified the printer cartridge, specifically the HP26A (Figure 1), as the core technology that cannot be easily reproduced [2]. Thus, we have sought to build a new bio-fabrication system that incorporates this cartridge. The waveform that "fires" the cartridge, i.e., produces a droplet, will quickly heat the resistance in a nozzle chamber and cause nucleation and the ejection of a drop of material. The parameters of this waveform shown in Figure 1 will be examined in order to optimize the electronics that create the firing pulse. The amplitude is found from literature reviews [3], however, the role of the period and pulse width in ejecting a droplet of biomaterial must be determined.

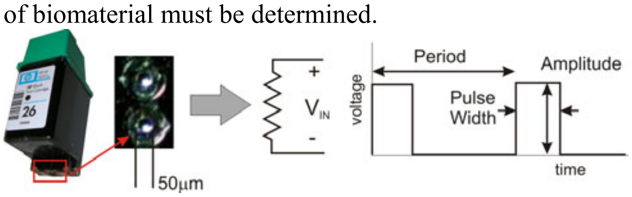

Figure 1: Cartridge with magnified nozzle orifice and electrical model with firing waveform.

Methods: In the first experiment a custom electronic drive circuitry was connected to a new HP26A cartridge containing the original ink. The hardware and software was configured to fire a single nozzle (from the fifty available on a single cartridge). The firing pulse width was varied from 1.5 to 2.75μs in increments of 250ns with the period held constant at 1ms. The print head was fixed 3mm above a piece of photo paper which was moved by the positioning system. The presence and shape of the drop was used to compare parameter settings.

In the second experiment, the cartridge was loaded with suspended cells at 7.7million/mL in a HBSS-DMEM solution with added EDTA to reduce clogging [4]. A series of 1000 pulse bursts were executed. An initial firing frequency of 1000Hz (period=1ms) was used until the cartridge stopped producing drops; the frequency was then reduced until printing commenced.

In the third experiment glycerol was printed in varying viscosities. The frequency (1/period) was increased to determine the maximum firing frequency.

Results: The printer cartridge produced approximately the same drop shape over the pulse width range 2 to 2.5μs. Printing for long periods of pulse widths over 2.5μs caused the nozzle to stop printing without any observed physical damage. Although outside of the stated range, it was found that a 5μs pulse width caused observable damage to the nozzle. Drops were not reliably formed below 1.75μs. Figure 2 shows the results of the cell printing trials; Figure 3 shows results from the glycerol study.

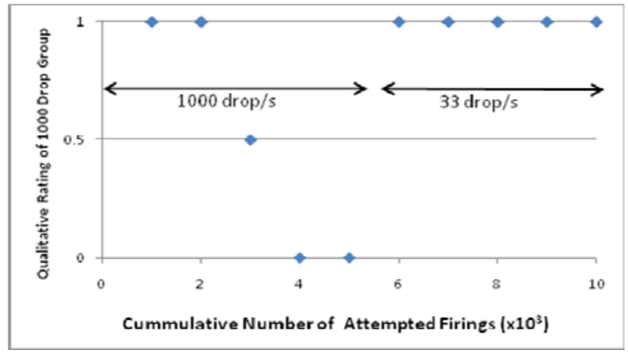

Figure 2: Cell Printing - plot of successive firings of the single nozzle, each point represents 1000 attempted firings. Qualitative rating system:1=good,0.5=printed with spatter (satellites around main drop), 0=not all drops printed.

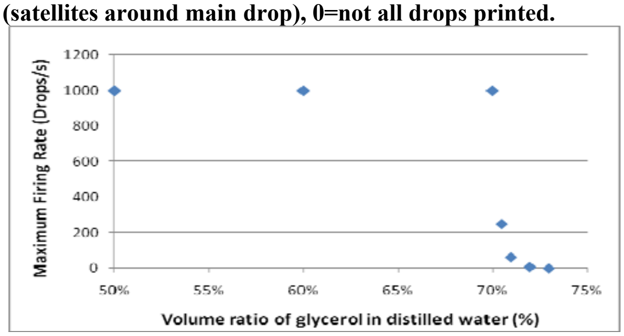

Figure 3: Glycerol Printing – plot of the maximum firing rate as the viscosity of the glycerol water mixture is changed.

Conclusions:

The range of pulse widths for acceptable printing was established to be 1.75 μs – 2μs (for the ink media), below which there is insufficient printing energy and above which the resistive heating element burns out. The nozzle firing frequency (1/period) must be matched to viscosity. Too high of a firing frequency relative to the viscosity stops drop production. Future work will be performed to refine these relationships.

References:

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[3] Harmon, J.P. and Widder J.A., "Integrating the printhead into the HP DeskJet printer", *Hewlett-Packard Journal: Technical Information from the Laboratories of Hewlett-Packard Company 39(5),* pp. 62-66, October 1988.

[4] Parzel CA, Pepper, ME, Groff, RE, Burg T, Burg, KJL. "EDTA as an Anti-scalant and anti-aggregant in bioprinting applications". *Transactions of the 33rd Annual Meeting of the Society for Biomaterials*, Poster Presentation, Vol. 31, (Sept., 2008).

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