New Bubble Jet Print Head for Photo-Quality Printing

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Abstract

With recent advances in inkjet technology, many efforts are being made to achieve print quality comparable to a silver halide photograph. Technology for stable ejection of fine droplets is essential for this purpose. A novel droplet ejection system for the bubble jet, completely different from a conventional system and suitable for ejecting stable fine droplets, will be presented here. We have named the new system "MicroFine Droplet Technology". The new system advancements are :

1) Higher droplet ejection efficiency
2) Uniform droplet volume

These are the key requirements to produce photo-quality images using fine droplets. In addition to the ejection system, a totally new manufacturing process that realizes the new bubble jet system will be presented. This manufacturing process is able to produce highly precise nozzles at lower cost and meet the demand for producing a high density multi-nozzle bubble jet head. We applied MicroFine Droplet Technology and new manufacturing process to our new bubble jet printhead on BJC-8500, introduced last March at the Seybold seminar.

The new printhead has 1536 nozzles and BJC-8500 prints A3+ sized printouts in photographic quality twice as fast as a conventional inkjet printer.

Introduction

The possibility of producing silver halide photograph quality printouts using an inkjet printer has been known for a long time. But until recently, the usage of an inkjet printer has been limited to printing documents, simple graphs and tables.

One reason for the limited usage was the computer system's poor ability to handle digital data for such high quality printouts: i.e. the CPU processing speed, memory size, applications, and input device (scanner). Recent innovation has changed the circumstances: CPU clock speed of over 300Mhz, high capacity low cost memories, and rapid popularization of digital cameras.

Another reason was the difficulty of inkjet head (nozzle) development capable of high quality output. The requirements necessary were:

1) Smaller droplets volume (below 10pl)
2) Higher requirement against banding
3) Higher stability of droplet ejection
4) Larger number of nozzles at low cost

MicroFine Droplet Technology

To solve these problems, we proposed a new droplet ejection system for bubble jet head [1 2]. Small droplets are generally obtained by reducing the orifice area. But, this results in unstable droplet ejection through ejection energy loss due to viscous resistance near the orifice. The change in droplet volume due to the change of resistance in the nozzle by ink temperature was another problem. The amount of droplet volume change is not important in printing documents, tables, and simple graphs, but it becomes crucial in printing high quality output like photographs. The heat pulse width was controlled to reduce the droplet volume change, but this alone was not enough for our purpose.

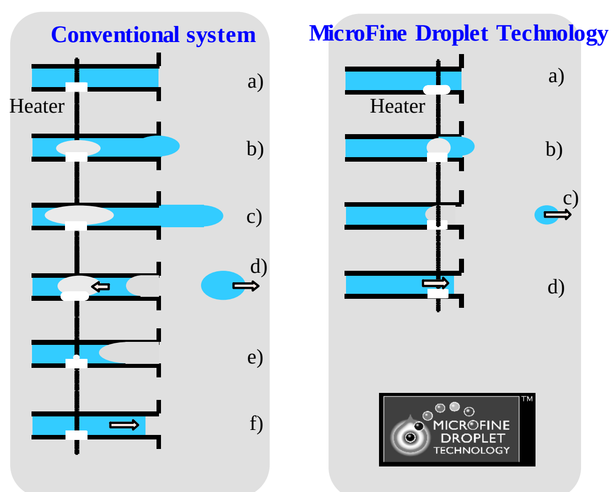

Figure 1 The difference between conventional and new droplet ejection system

Figure 1 shows our new droplet ejecting system. In a conventional droplet ejection system, shown on the left in Figure 1, the heater brings the ink start to boil, gas rapidly pressurizes the surrounding ink, and the ink comes out of orifice (b-c). Next, pressure inside the bubble decreases as the bubble grows rapidly, and the negative pressure pulls the ink back into the nozzle. Then, the ink outside the nozzle breaks up into droplets (d). The droplet volume depends on the break-up timing, initial bubble pressure, resistance of the nozzle, and other factors.

The right half of Figure 1 shows an example of the new droplet ejection system. The mechanism for the droplet formation is quite different from that of a conventional system. Initially, the ink starts to move outward by gas pressure, then, before the bubble starts to shrink, the ink moves out from the orifice and the bubble communicates with the ambience (c). Because there are no negative pressure bubbles, pulling back of the ink does not occur, and the ink outside the orifice form droplets. In this case, the droplet volume is equal to the volume of the ink pushed outward at the moment of boiling. In other words, all of the ink from the orifice to approximately the center of the heater becomes the droplet. The droplet volume depends only on the geometrical size of the nozzle, and not on bubble pressure or ink viscosity. That makes the droplet volume highly uniform.

Higher ejection energy efficiency is also obtained, due to no deceleration of ejection by a shrinking bubble. This high efficiency stabilizes ejection.

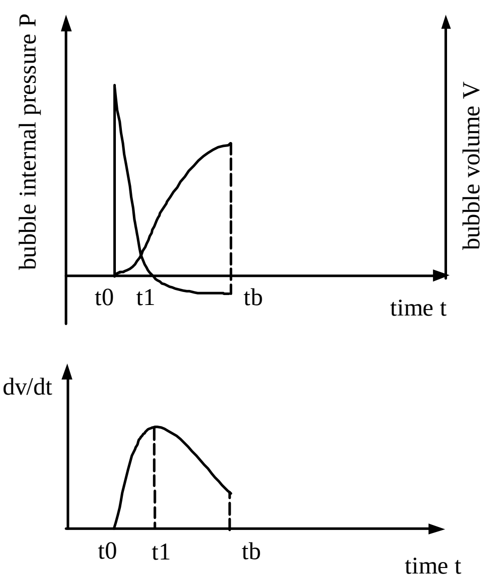

Figure 2 Bubble internal pressure and bubble volume

Figure 2 shows the change of the bubble pressure and the bubble volume over time. Boiling begins at t0 and immediately the pressure reaches the peak. The pressure declines as the bubble grows, reaching the atmospheric pressure at t1. The growth rate of the bubble dv/dt reaches approximately maximum at this point and second order differential of the growth rate equals zero ($d^2v/dt^2=0$). Though the bubble continues to grow by inertia, the growth rate decreases by the negative pressure inside the bubble and becomes negative in a conventional drop ejection system; Finally the bubble starts to shrink.

In our new droplet ejection system, the bubble communicates the ambience at tb after the second order differential of the growth rate turns to negative ($d^2v/dt^2<0$). In this example, dv/dt>0 at tb, so bubble shrinkage does not occur.

This is the main difference of MicroFine Droplet Technology.

New Manufacturing Process

Let's examine the dimensions of the nozzle design of MicroFine Droplet Technology. For a droplet volume of 10pl, the orifice-heater (OH) distance would be 25µm if the orifice area is 400μm^2 (22.5µm in diameter). The OH distance in a conventional system is about 60 to 160µm, thus the OH distance in the new system is very short. In addition, as the droplet volume is determined by nozzle dimensions, a high precision nozzle is required. Nozzle density must be high and the number of nozzles must be large in order to produce image by very small dots. So, we have studied new manufacturing processes to meet these demands.

In conventional manufacturing, film or the molded part, both with a laser ablated orifice, or the orifice plate made by an electroforming process is mated with a silicon substrate having a heater and electrode on it. These processes are similar in that the nozzle part is mated with the substrate. It is difficult to handle 25µm thin nozzle film, especially when it has a large area. Adhesion of the nozzle film with substrate is another problem; thick adhesive leads to a non-uniform OH distance and, on the other hand, thin adhesive leads to defective adhesion.

Our new manufacturing process is presented below. We have applied semiconductor manufacturing processing to the inkjet nozzle manufacturing process. First, the nozzle material is coated on a silicon substrate, patterned using photomask, then cured. The nozzle is finished by repeating the process.

Figure 3 Shows a cross section of the bubble jet head around the nozzle made using the new manufacturing process. Figure 3a) shows the head at mid-process, just after the nozzle material is coated. Following figure 3a), the nozzle material is photo patterned, an ink inlet is made, and the remaining material is flushed away. Figure 3b) shows the final state of the process. This process is advanced in its:

1. Large allowance in nozzle thickness - By changing the coating condition, nozzle thickness can be freely selected, which means that the drop volume can be freely selected.
2. High nozzle dimension accuracy - By controlling the coating parameters, it is possible to achieve the uniform nozzle layer thickness throughout the substrate. By eliminating the adhesion process, the layer thickness is equal to the nozzle thickness. The orifices are also precisely made because of the semiconductor patterning process.
3. Large nozzle area - It is easy to create a large surface with many nozzles.

4. High alignment precision - Alignment between the heater, nozzle and the orifice is high, due to the high accuracy of the semiconductor mask aligner.
5. High resolution - Suitable for high density (over 600dpi) nozzle.

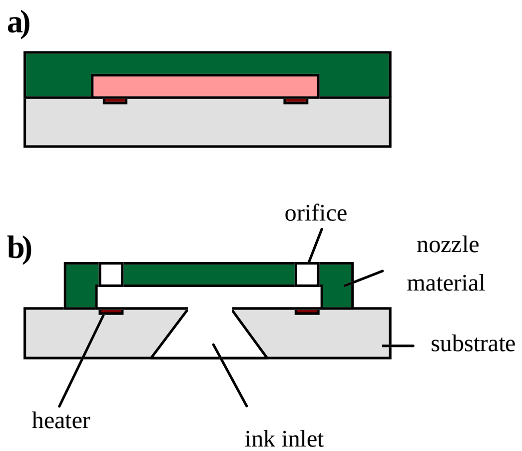

Figure 3 Bubble jet head cross section around the nozzle

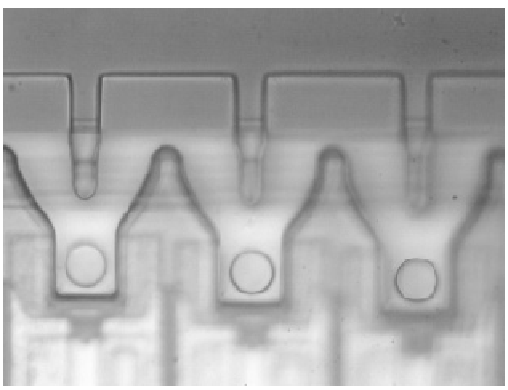

Figure 4 Microscopic view of new nozzles

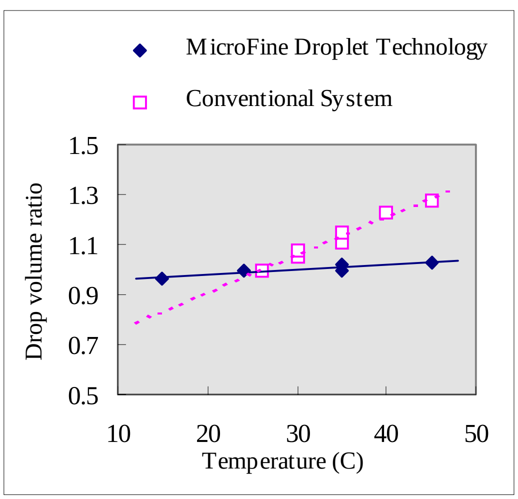

Figure 5. Drop volume ratio of MicroFine Droplet technology and Conventional system

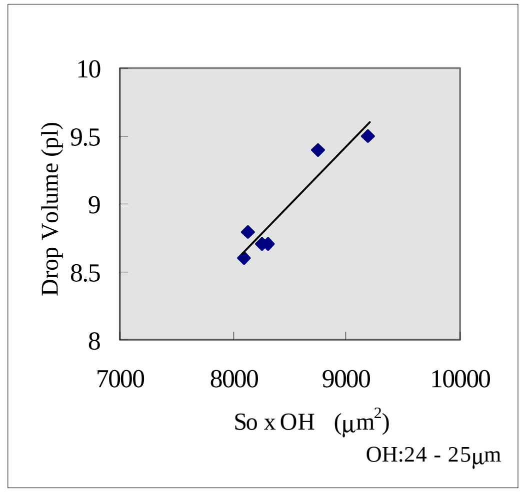

Figure 6 Drop volume on different nozzle dimension

Results

Figure 4 Shows the microscopic top view of the nozzle made using the new manufacturing process. The OH distance is 25μm and the orifice area is 320μm^2.

Figure 5 Shows the drop volume vs. ink temperature characteristics of the nozzle. The drop volume vs. ink temperature characteristics of a conventional system are also shown. The droplet change rate of MicroFine Droplet Technology is 0.2%/°C which is about 1/4 that of a conventional nozzle, 0.9%/°C .

Figure 6 Shows the relation between the drop volume and nozzle dimensions. The drop volume is almost equal to the volume of the ink between the orifice and the heater (So x OH).

From these results, it is concluded that the new system has a very uniform droplet volume against temperature change, and the droplet volume almost equals to the volume of the ink from the orifice to the heater, proving that MicroFine Droplet Technology is useful.

Figure 7. BJC-8500

We had then developed an 600dpi-256nozzle bubble jet-head applying MicroFine Droplet Technology and new manufacturing process. The new printhead is incorporated in our new BJC-8500 Printer. Combining this head and six-color ink (Black, Cyan, Magenta, Yellow, light Cyan, Light Magenta), the BJC-8500 produces photo quality printouts of A3+ size with high throughput.

Using MicroFine Droplet Technology, we are now developing a new nozzle which can produce even smaller droplets. We believe that it will be possible to produce completely grainless printouts in the near future.

Summary

The stable ejection of fine droplets is realized using MicroFine Droplet Technology. Photo quality printouts from an inkjet printer is also realized. In addition, the production of a high density multi-nozzle bubble jet head is realized using a new manufacturing process based on semiconductor processing, which features high accuracy, large allowance of nozzle number and droplet volume.

References

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Biography

Mineo Kaneko received his B.S. and M.S.degree in Physics from Waseda University, Tokyo, Japan in 1982 and 1984. Subsequently he joined Canon and has been working on development of bubble jet head.

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