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Inkjet Printing Technology

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Abstract

To support color and high printing quality of a printer, we developed a piezoelectric type inkjet print head. In this system we adopted piezoelectric share mode, which is superb in ink drop control and can be applied to many fields.

1. Introduction

As the Internet extends the sharing of information by electronic mail, making it an everyday experience, printers, the output machines of information, are becoming even more important. For printers used for this purpose, color and high resolution printing are critical, targeting quality of photographs, and inkjet printers are suitable for this purpose.

To meet this demand, Okidata is developing an inkjet print head.

Inkjet printing methods are roughly divided into the piezoelectric type and thermal type, and as Table 1 shows, each type has advantages and disadvantages. This paper introduces the piezoelectric type, which has the following features.

1. Ink delivery quantity can be adjusted by drive control. Drop size control is easy and high print quality, based on grayscale representation, is possible.
2. Printer does not deteriorate and can be used almost indefinitely because heat is not generated. Reliability is superb.
3. Suitable for increased speeds

We targeted the direction of our development to a piezoelectric permanent type inkjet head, which is superb in grayscale representation and is non-disposable, and are conducting various types of experiments.

This time we report on the basic operation of a shear mode type inkjet head utilizing the shear mode deformation force of piezoelectric elements which are not generally used, drop diameter control, and the measurement technology required for this development.

	Type	Piezoelectric type	Thermal type
Head	Life	○	×
	Print quality	○	△
	Power consumption	○	△
	Permanent / disposable	Permanent (replaceable)	Disposable (refill type available)
	Reliability	○	△
	Size	△	○
	Cost	×	○

Table 1: Comparison of piezoelectric type and thermal type

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2. Print head

2.1 Operation principle

The deformation of piezoelectric elements is utilized in two ways, thickness deformation mode shown in Figure 1 (b), and sliding deformation mode (shear mode) shown in Figure 1 (a). The former utilizes thickness deformation, which is generated by applying an electric field in the same direction as the polarization direction of the piezoelectric element. The latter utilizes sliding deformation, which is generated by applying an electric field perpendicular to the polarization direction of the piezoelectric element.

Figure 2 shows the operation principle of an ink pressure chamber, and Figure 3 shows the structure of the head. The ink pressure chamber is comprised of a small slot created by two piezoelectric crystal plates which are bonded together. Figure 2 is a conceptual drawing showing operation when voltage is applied to the piezoelectric walls on both sides of the ink pressure chamber. Because of this operation shear mode deformation occurs to both walls, and ink drops are delivered from the ink pressure chamber. (a) indicates standby status. When a + voltage and - voltage are applied to the electrode shown in (b), an electric field is generated and the nozzle walls open. When voltage is the reverse of (b), a reverse electric field is generated, which makes the nozzle walls curve in the closing direction, delivering ink drops. The nozzle walls are then returned to initial status, as shown in (d).

The features the method used for this head compared with other piezoelectric methods are as follows.

a. Required components are few and the structure is simple (two plates of piezoelectric materials can create 50 ~ 60 channels).

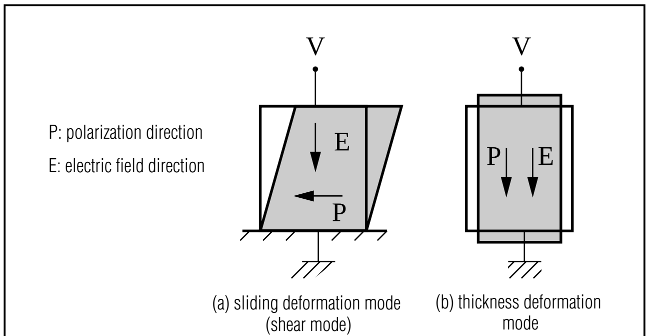

Figure 1: Deformation mode of piezoelectric crystal

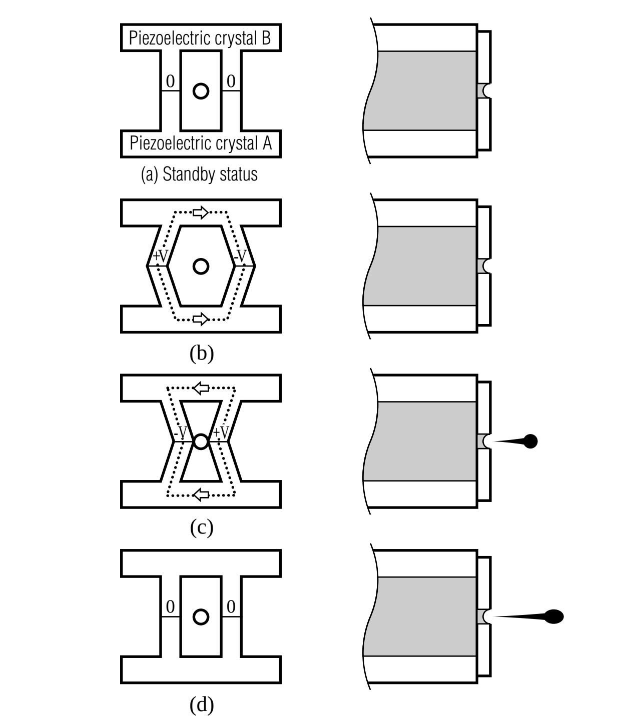

Figure 2: Principle of operation

b. An ink channel can be created directly in piezoelectric material, without bonding with other components, such as a spring. This minimizes characteristic dispersion among channels, and high density packaging is also possible.

2.2 Piezoelectric material

Since the deformation force of very small piezoelectric walls is utilized as an ink delivery force, the piezoelectric material to be used must have superb uniformity of characteristics. Table 2 shows some of the characteristics of the piezoelectric materials that we are evaluating.

For piezoelectric characteristics, the resonance characteristic of piezoelectric materials is measured by an impedance analyzer, and is calculated by the G.B. method. Figure 4 shows an example of the measurement output of the analyzer.

Small cavities inside piezoelectric material have a great influence on uniformity of characteristics and on the reliability of a very small ink pressure wall. We discovered a

Manufacturer	Piezoelectric constant (d15) (310^{-12}m/V)	Electromechanical conversion coefficient (K15)	Curie temperature (Tc, °C)	Density	Polarization length (mm)
Evaluation material	870	0.75	250	○	Approx. 60
Another material A	880	0.73	195	△○	Approx. 65
B	720	0.735	315	×	10~15
C	745	0.735	315	△	10~15
D	750	0.675	282	×	10~20
E	690	0.71	315	×	8
F	(550)	(0.66)	300	×	

Table 2: Comparison of characteristics of piezoelectric materials

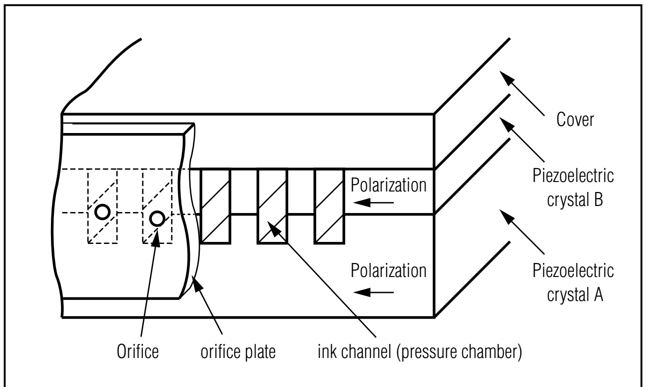

Figure 3: Schematic of print head structure

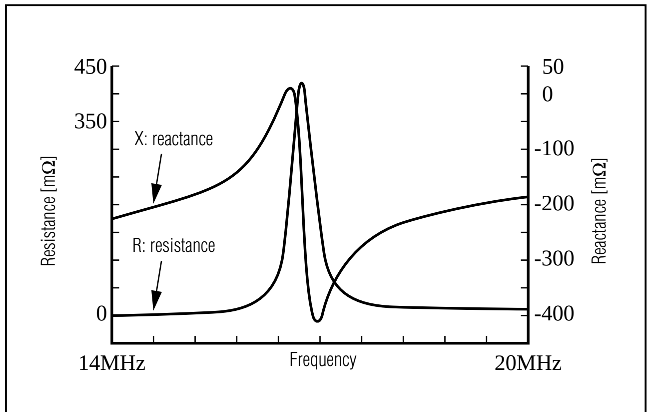

Figure 4: Piezoelectric resonance output waveform

method to non-destructively analyze the cavities in piezoelectric material by using an ultrasonic microscope.

This measurement principle involves detecting cavities and foreign substances in material by measuring elasticity in the micro areas of the material. Figure 5 shows the measurement principle and Photo 1 shows photographs of measurement results. Piezoelectric material M in the far right photograph has less white dots than 0-9 and T-H materials, indicating higher uniformity.

3. Drop size control of delivered ink[1]

In the piezoelectric method, deformation time of a piezoelectric element is variable so as to change the drop size of delivered ink drops. This makes it possible to control drop quantity and to implement high resolution grayscale representation. This section presents details on the ink delivery principle and describes drop size control using simulation results.

Figure 6 shows the changes of pressure inside a nozzle.

1. Driving starts at point "S" (walls of nozzle open)
   At this time, pressure inside the nozzle suddenly drops, as seen in "a". Then as "b" shows, pressure gradually increases by the fluid vibration in the nozzle and in the ink itself.
2. When the walls of the nozzle are closed at point "A", pressure further increases as seen in "c", and ink drops

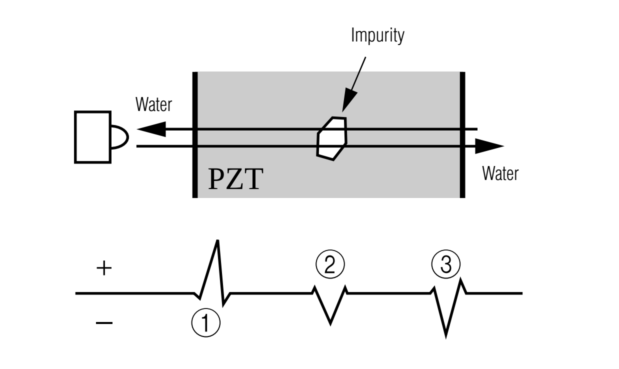

Figure 5: Principle of ultrasonic microscope measurement

are delivered. A means of controlling the drop size is to change drive time "T1".

3. After this, vibration remains as seen in "d", for the same reasons in "b".
4. Drops are actually delivered not at the moment when the walls of the nozzle are closed but during the latter half of "d", because of the viscosity of ink and for other reasons. Figure 7 shows the change of position of meniscus[*1] (ink surface in the orifice[*2]). The negative direction of the ordinate in the graph is the ink drop delivery direction.
   - I When the walls of the nozzle are opened at point "S", the position of meniscus moves back into the nozzle.
   - II When the walls of the nozzle are closed at point "A", drops are delivered gradually.
   - III The position of meniscus rapidly moves backwards at point "P", because delivered drops are separated from the nozzle at this point. (Figure 8 shows the result of simulating the status of ink drops at point "P".)
5. The wall status of the nozzle returns to the original status at point "B".

In the drive method shown in Figure 6, point B is not used for drop size control but for attenuating residual pressure vibration (for enabling continuous driving) in the simulation result from "e" to "f" shown in Figure 6.

If point "B" in Figure 7 is set between point "A" and point "P", drop size can be controlled by the position of point "B", that is, drive time T2.

In this way drop size can be controlled by making drive time variable. The result of this simulation is correlated with the actual observation result, showing that simulation is an effective development means.

4. Ink delivery measurement technology

This print head has an enormous number of ink channels and measurement parameters, so automatic measurement of ink delivery performance is indispensable for ink jet development. Figure 9 shows a block diagram of the automatic measurement system, and Photo 2 shows captured ink drops. In the automatic measurement of ink delivery, two cameras are used to photograph images on the front and side of delivered drops, because the curvature of ink drops must be measured. A dedicated head driver control card enables driving under the same conditions of the printer. This system has the following measurement functions.

a. Ink delivery speed
b. Ink delivery linearity
c. Ink delivery volume
d. Number of satellites
e. Internal insulation in ink channels

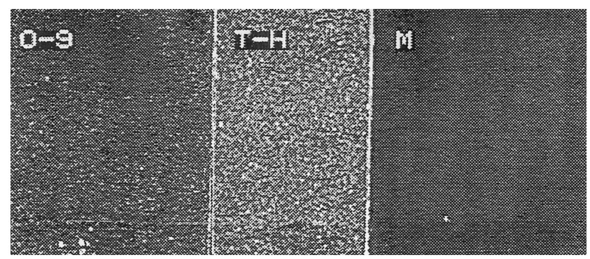

Photo 1: Photograph of ultrasonic microscope measurement results

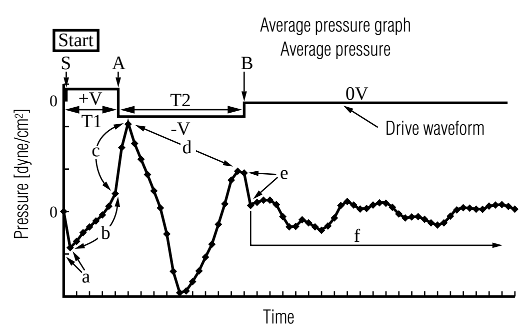

Figure 6: Pressure change in nozzle (simulation result)

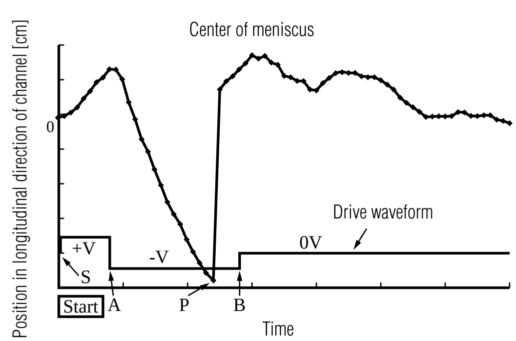

Figure 7: Change of meniscus position (simulation result)

*1 Meniscus: ink surface in orifice
*2 Orifice: narrow outlet portion at tip of nozzle

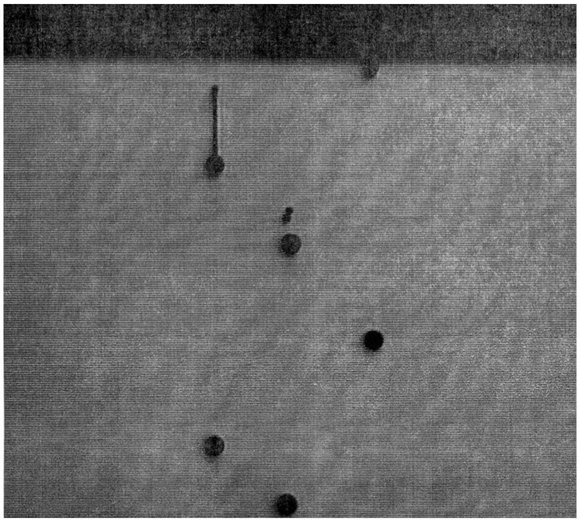

Photo 2: Photograph of captured in drop image

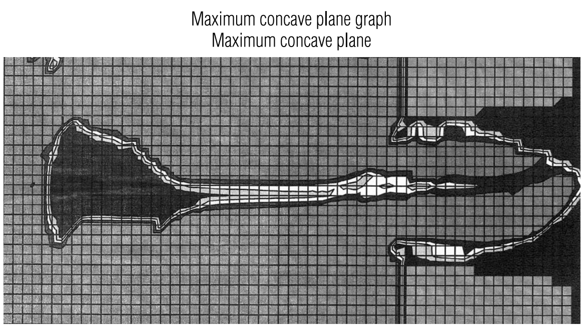

Figure 8: Moment of drop formation (simulation result)

5. Conclusion

We developed a piezoelectric shear mode type inkjet print head. This method, which can control the drop size, is one of the most suitable methods for inkjet printer heads, and has the primary focus of photographic quality printing. For the development of inkjet printers in the future, further advancement of observation, measurement and simulation technologies are effective.

6. References

1. Ink Jet Technologies, IS&T, 1996

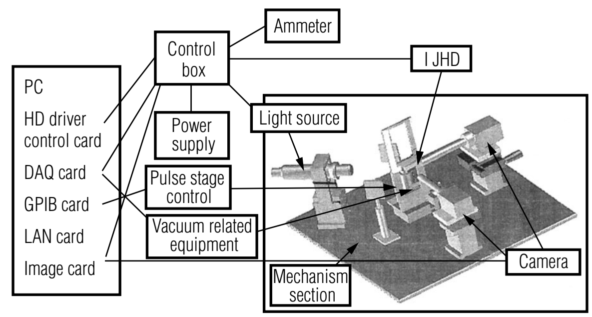

Figure 9: Block diagram of measurement system