New Print Head Technology for High Productivity and Stability

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Abstract

SII Printek produces printheads characterized by their high productivity. Our ink-jet printheads realized such high productivity with edge shooter structure operating in shear mode until now. Most especially, 508GS model has been popular covering a wide range of ink chemistry and capable of jetting at a high frequency thanks to its isolated channel structure. However, even higher stability at high production rate is demanded in any industrial market, particularly those prints in single pass. Hence we developed a new product which adopted the following techniques to cope with such demands.

Firstly, we adopted side shooter structure where a nozzle is located in the center of pressure chamber with openings at both ends to enable ink circulation across. Thereby we can save a large quantity of ink consumption wasted for filling of ink and cleaning of nozzle. Continual ink flow beside the nozzle realizes self-recovery of meniscus as well.

Secondly, we adopted our isolated channel structure where discharging and non-discharging channels are alternately grooved and only the latter are actively driven.In this way, electrodes of discharging channels immersed in ink are free from any corrosion and active channels can operate at a high frequency since they are isolated from each other and hence free from crosstalk.

Thirdly, we adopted a cantilever structure where the channel walls of the actuator are held rigidly by stiff material at one end and flexibly at the other, from which electrodes extend covering about half height of the wall. This allows us to effectively drive the discharging channel without too much modifying the simple conventional process. Incorporating these three structures together allows us to jet a large volume of drop at a high frequency, but such a large ink flow digitally driven causes big pressure shock occurring at onset and end of a print streak, starving and over-pressuring the printhead in turn. We introduced a dumping structure to supress such a big shock affecting the actuator operation. Thus we could achieve good printing sustainability that can endure any pressure fluctuation, not only due to sudden change in pinting streak but also from outside disturbance. In conclusion, our new inkjet printhead RC512 realized very high productivity and sustainability for industrial printing.

Its productivity exceeds our existing product lineup by far, and we are amazed to see a stable discharge is possible with such productivity. We are further developing a new model evolved in the line of this structure aiming at even higher performance.

Introduction

SII Printek Inc. has developed printheads that can make high frequency jetting with many kinds of inks. We explain about 508GS printhead as a typical example. Figure.1 (a) shows its structure. There are two identical basic units laminated back to back to each other sharing a single nozzle plate with two arrays of nozzles for each unit. This basic unit is composed of an actuator plate made of PZT with an array of grooves and a cover plate laminated onto it to form channels in between. Half of the channels are connected with ink manifold through inlet holes built into the cover plate and discharges ink. The other half of channels are not connected with the manifold and alternately sits between discharging channels isolating them from each other. Discharging channel positions of two units are staggered and therefore a cross section along the channel reveals discharging ones of a unit at the top and non-discharging ones of the other unit at the bottom. There are electrodes formed on the surface of each channel sandwiching channel walls in between. The nozzles are at the end of discharging channels to make an edge shooter [1].

Figure.1 (a) 508GS Structure, (b) 508GS cross-sectional view

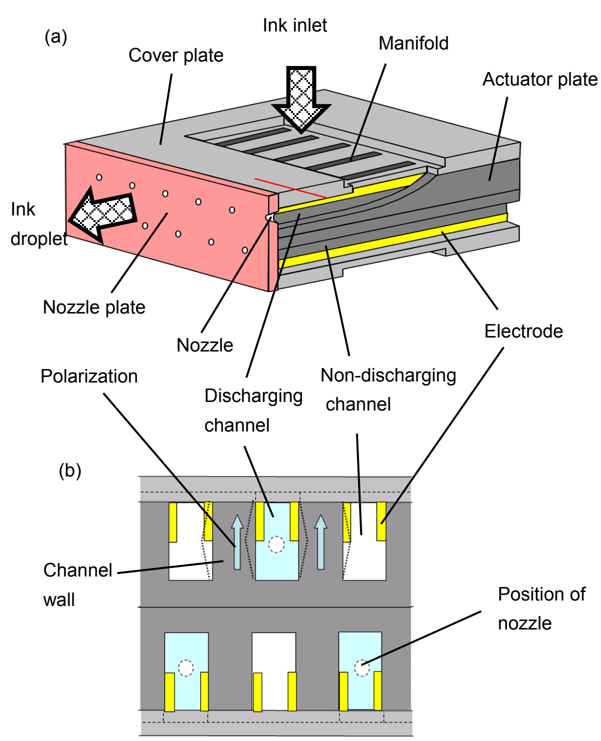

Figure.1 (b) shows the principle of discharge operation. A driving voltage is applied to electrodes on non-discharging channels while those on discharging channels are grounded. This causes poled channel walls deform in sheer mode expanding discharging channels to introduce ink from the manifold. Then the voltage gets back to zero at a right timing and the walls to the original position, causing discharge. A series of such operations can make ink jet from nozzle at a high frequency. Since the discharging are grounded and no voltage applied to ink, the printhead can jet conductive ink (e.g., water based ink) without fear of electric corrosion.

However, there are increasing demands for higher discharge, better stability and jetting availability of a wider range of ink including those with a higher viscosity and a larger particle size. Hence we developed RC512 printhead with several new features described below and confirmed it has much higher stability and productivity. It provides continued jetting with easier maintenance at a much reduced frequency and misfiring nozzle by any reason recovers immediately. Uniformity of operation across the nozzles and over the jetting frequency are improved. Increased productivity is obtained at higher jetting frequency and a range of drop volumes are also available.

Structure of Printhead

Recirculation Structure

An ink flow passing by the nozzles can effectively recover missing nozzles and also prevent ink pigments from setting inside the channels. We introduced an ink recirculating structure without too much modification of our conventional manufacturing methods.

Figure.2 (a) shows recirculation structure of RC512 printhead and Figure.2 (b) its cross-sectional view of alternating discharging and non-discharging channels. It has two separate manifolds at each end of discharging channels enabling ink flow passing through and nozzles are located on the bottom of the channels at their center.

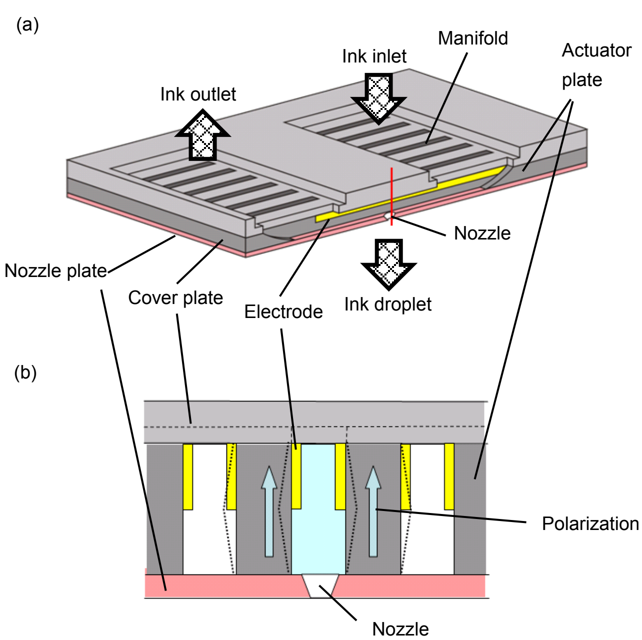

Figure.2 (a) RC512 Recirculating Structure, (b) Cross-sectional view

Its operational principle is the same as 508GS printhead. Side walls of discharging channels are first deformed by an applied voltage expanding its volume, and then get back to their original shape to jet an ink drop out of their nozzles. Continuous ink flow can be generated through the channels by an external ink supply system, which could flow away any debris or air bubbles in the ink and recover misfiring nozzles. Figure.3 exhibits a print result demonstrating automatic nozzle recovery after misfiring introduced deliberately by a mechanical shock applied to the ink supply tube connected to the inlet manifold.

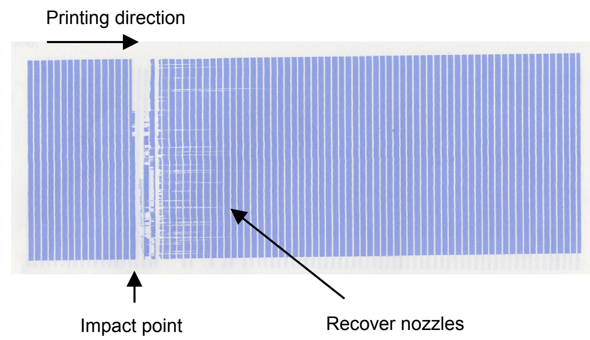

Figure.3 Print result of nozzle recovery

Its jetting frequency is 10.5 kHz, paper feed speed 100mm/sec and print pattern repetitions of 192dot discharge and 64dot non-discharge.

Recirculating ink flow prevents ink pigment setting inside the printhead as mentioned. Ink flow passing beside the nozzles always refreshes their menisci and keeps their ink from drying [3].

Beam/Cantilever Structure

In order to allow the ink flow pass through the channels beside their nozzles, we put the nozzle plate on the bottom of channel walls. In conventional configurations of piezo printhead, their pressure chambers are surrounded by stiff materials confining ink inside in order to effectively apply pressure from their piezo actuator. Since our nozzle plate is less stiff than the channel walls and the cover plate, we first put a 100 micron thick stiff plate between the nozzle plate and the channel walls to reinforce the pressure chamber. Then we noticed that ink was discharged from an inactive nozzle (that is no driving voltage applied) when sandwiched between active nozzles on its both sides as shown in Figure.4.

This was because the deformation of active channel wall transmitted to the adjacent wall through the reinforcement plate resulting in a crosstalk between adjacent channels. We also found that the reinforcing plate makes the ink flow away from the nozzle meniscus according to its thickness and aperture size to the nozzle and impede automatic recovery of missed nozzles.

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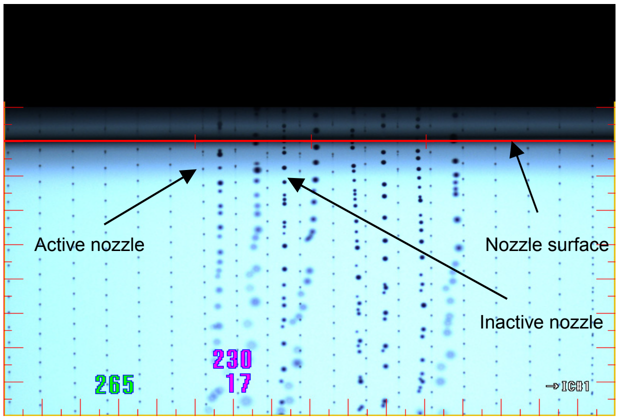

Figure.4 Jetting of inactive nozzles

We tried to find what would occur if we remove the reinforcing plate and put the nozzle plate direct onto the channel walls. Figure.5 shows a result of FEM simulation of channel deformation when a driving voltage is applied.

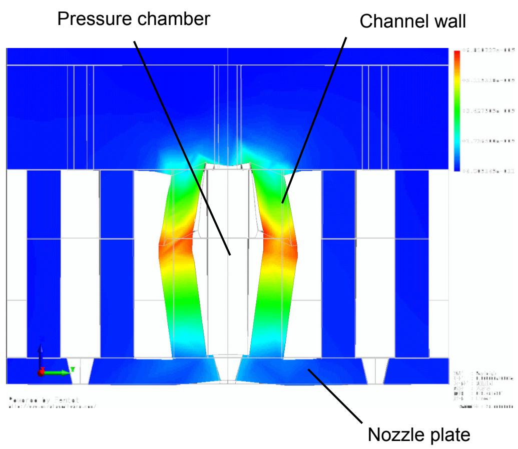

Figure.5 FEM simulation of channel deformation

We can see that deformation of the channel walls are absorbed by a slight deformation of less rigid nozzle plate and little pressure is transmitted to the adjacent walls. Fulcra of channel walls at the nozzle plate slightly moves laterally outwards and vertically inwards. This means the wall moves both as a beam between the cover plate and the nozzle plate and a cantilever supported by the former.

We produced printheads in this structure and confirmed that the crosstalk between adjacent channels were suppressed.

Pressure chamber parameters such as wall thickness, channel depth and nozzle plate rigidity should be optimized for a desirable jetting operation.

Structure for the Stability

RC512 has two staggered channel arrays as shown in Figure.6. Each channel array has inlet and outlet manifolds at both ends to obtain a symmetrical acoustic structure, but wirings to connect the electrodes with a driving circuit must be formed on one side, which makes the pressure chamber electrically asymmetrical.

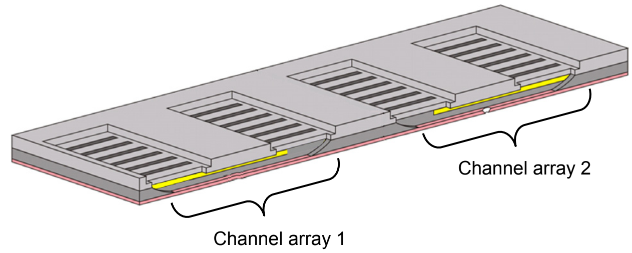

Figure.6 RC512 Channel arrays

We noticed this asymmetry reduces acoustic efficiency of the pressure chamber. In order to ensure electrical symmetry, we form an insulation layer on the channel wall outside of the acoustic cavity by vapor deposition, as shown in Figure.7. This makes the wall outside the cavity including the wiring section almost insensitive to the driving voltage.

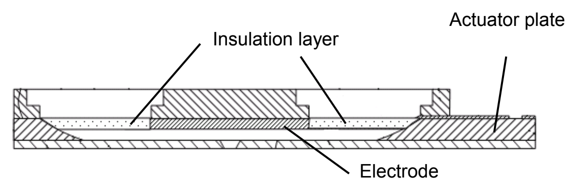

Figure.7 Insulation layer passivating outside of the cavity

Figure.8 shows channel wall impedance with and without the insulation layer [2].

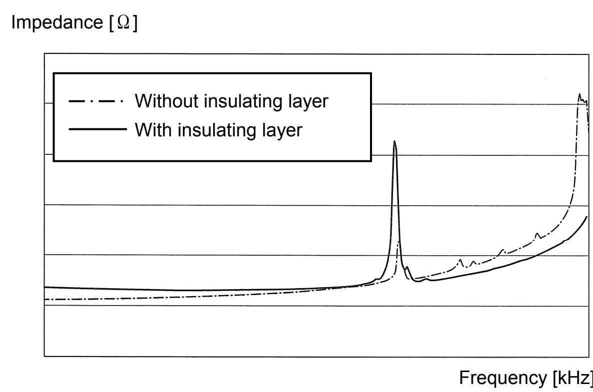

Figure.8 Frequency impedance with and without insulating layer

A single sharp peak is observed with insulating layer while the corresponding peak is suppressed and other peaks appear in the robe towards higher frequency without it, suggesting excitation of spurious acoustic modes. We succeeded to suppress these spurious modes with insulation layer and achieved higher discharging efficiency and better frequency characteristics. We could produce this structure with our conventional manufacturing methods like dicing and vapor deposition.

Structure of Ink Manifold

We incorporated a new configuration of ink manifold with a film comprising its ceiling which absorbs and damp out pressure waves radiated from the channels into the manifold. It is shown in Figure.9.

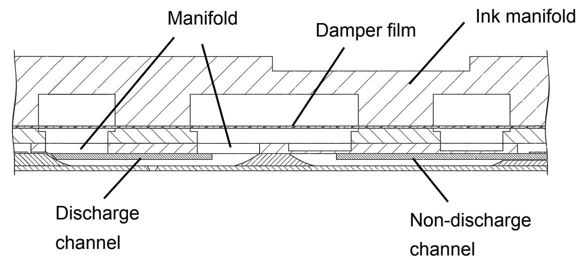

Figure.9 Manifold with a damper film

This reduces crosstalk between the two channel arrays without any increase of the flow resistance of the manifold. It also enables ink discharge at a higher frequency for increased productivity [4].

Figure.10 shows an example of jetting at 67.5 kHz where all nozzles continuously jet droplets of 27.8pL with excellent uniformity.

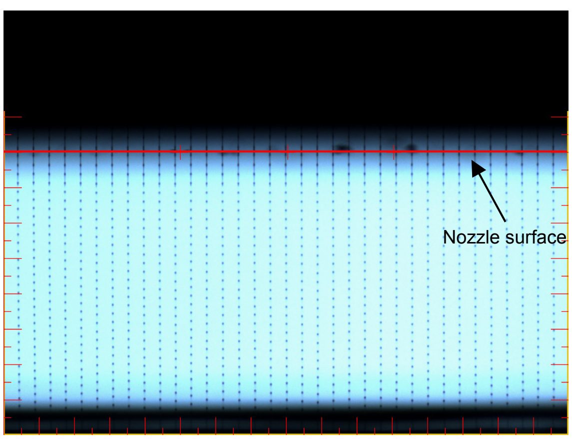

Figure.10 High frequency discharging of 67.5 kHz

Table.1 shows a comparison of RC512 and 508GS printheads. RC512 realizes 3 times higher discharge than that of 508GS due to its stable jetting at a higher frequency. The former is much less susceptible to any disturbance like mechanical shock applied to itself and its supply tubing, thanks to this manifold configuration incorporated with a damper film.

Table.1 Comparison with 508GS and RC512

	508GS	RC512
Number of nozzles	508	512
Productivity per nozzle [nl/sec]	630	1877

Capability to jet wide range of ink

It has been proven that RC512 is capable of jetting a wide range of ink with high stability and productivity as listed below.

Table.2 Properties of various ink and discharging result

market	Tile	Tile	Tile
Ink type	Oil	Oil(Glaze)	Water
Specific gravity [g/L]	1.380	1.238	1.234
Particle size D90 [nm]	208.7	1824	-
Conductivity [uS]	0.01	0.03	12570
Jetting temp. [deg C]	45	45	30
Viscosity at Jetting temp. [mPas]	14.6	14.3	13.7
Productivity per nozzle [nl/sec]	1433	1524	1535
Jetting performance	Good	Good	Good

market	Decoration	Glass	Edible
Ink type	UV	Solvent	Water (Alcohol)
Specific gravity [g/L]	1.068	1.571	0.914
Particle size D90 [nm]	615.5	634.5	326.6
Conductivity [uS]	1.76	1.69	19800
Jetting temp. [deg C]	40	25	25
Viscosity at Jetting temp. [mPas]	11.1	17.8	9.7
Productivity per nozzle [nl/sec]	1529	1316	1542
Jetting performance	Good	Good	Good

RC512 is found useful for a wide range of applications with high productivity and stability. Variety of adaptable ink includes those for ceramic tile containing large particles [5], UV curable, aqueous with high conductivity and volatile ones like solvent or water based ink containing alcohol.

Conclusion

We developed RC512 printhead which provides high productivity and stability in various industrial applications with a wide range of ink. This was possible with the new features incorporated in it. We evolve it to the next RC 1536 printhead with a larger number of nozzles at a higher resolution.

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References

[1] Harvey, R. A. and Manning H. J., "Xaar Greyscale Technology", Proc. NIP 15, 35-39 (1999)

[2] Antohe, B. V. and Wallace, D. B., "Acoustic Phenomena in a Demand-Mode Piezoelectric Ink-Jet Printer",Proc. NIP 17, 885-889 (2001)

[3] Eric Hanson, Recent Progress in Ink Jet Technologies II (IS&T, Springfield, VA, 19999) pg. 18

[4] Darling, D. D., "Frequency-Dependent Fluidic Inductance and Resistance in Inkjet Passages",Proc. NIP 20, 877-882 (2004)

[5] Harvey, R. A. and Sainz, J. G., "Digital Printing Applied to Ceramic Decoration",Proc. NIP 16, 516-518 (2000)

Author Biography

Yoshinori Domae acquired a bachelor's degree in Tokyo Denki University in 2004, majoured mechanical engineering. He joined Seiko Instruments Inc. in 2006 working in Seiko I Infotech division in charge of design and development of industrial inkjet printers. He moved to SII Printek Inc.in 2011 and has been engaged in developments of RC512 and RC1536 printheads since then.