A Drop-on-Demand Inkjet Printhead for a Wide Range of Applications

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Abstract

More and more drop-on-demand inkjet printheads are entering the market differing in the principle of droplet ejection such as bubble-jet and piezo technologies. Every major player in this field has his own technology patented, which has its advantages and drawbacks. In addition, the patent situation in this area turns out to be quite demanding for any independent printhead manufacturer to enter the market and to be successful, as the main patent owners have a rather restrictive license policy. Therefore, independent companies find themselves often unable to manufacture their own inkjet printhead based on the current technologies.

In this paper, the technology of an independent proprietary inkjet printhead is presented. It demonstrates the simple working principle and the wide range of applications such as printing, fluid dispensing or defined droplet formation. Special emphasis is directed to a variation of basic printhead designs necessary to meet the specific needs of each application. Moreover, the function and the innovative aspects of this technology are described in details with examples of potential industrial applications.

Introduction

There are many different inkjet printheads on the market exhibiting a broad variation of printhead designs.[1] A basic graph of the drop-on-demand (DOD) inkjet technologies is shown in Figure 1. Fundamentally, DOD inkjet printing technology is divided into bubble-jet and piezo technology depending on the mechanism used in the drop formation process.

All piezo printheads have a common working principle: A piezoelectric element is changing the volume of an ink chamber inducing drop ejection through the nozzles. The geometry and movement of the piezoelectric element divide the printheads into different classes.

Both, the bubble-jet and piezo technology, are protected with hundreds of patents. Therefore it is impossible to enter the market based on known technologies without infringing other patents. The aim of Pelikan Produktions AG was to develop and protect an own piezo inkjet printhead: The bend mode actuator. This class of printheads, which should be distinguished from the flex mode heads, will be now further discussed.

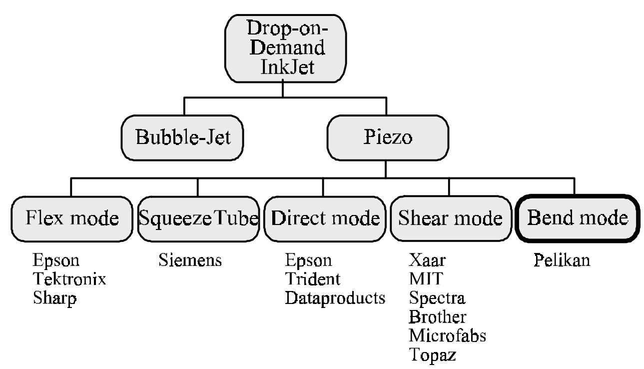

Figure 1: Inkjet printhead technologies

It was already suggested by Bolmgren and Nilsson [2] to use a bend mode actuator for an inkjet printhead. They experienced different problems like crosstalk with neighboring channels, a small range of working frequency, the necessarily high supply voltage and the complex manufacturing processes. These drawbacks prevented this principle from being further developed.

Pelikan Produktions AG improved the basic system. Today it is possible to manufacture walls placed between the single bend mode actuators. For that purpose it is necessary to reach a very high aspect ratio for the walls providing the decoupling of the channels and improving the printhead efficiency. Another progress was the use of multilayer piezoceramic material. This resulted in a reduction of the driving voltage. Based on these developments it is nowadays possible to build a competitive inkjet printhead with bend mode actuators, as designed and patented by Pelikan Produktions AG [3].

Printhead design

The bend mode actuator printhead comprised four major parts such as the channel plate, the piezo actuator, the nozzle plate and the nozzle foil (Figure 2).

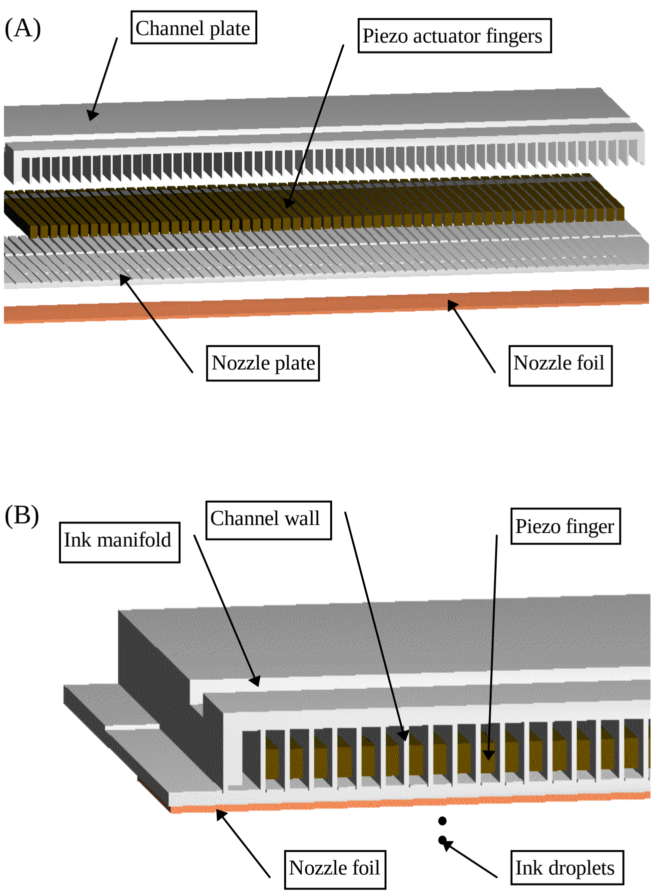

Figure 2: Major parts of an bend mode actuator printhead (A) before assembly (B) assembled

The channel plate provides the separation walls necessary to prevent crosstalk effects. The manifold for the ink delivery is also part of this channel plate. The bend mode actuator which is a piezoelectric multilayer ceramic with an active and a passive part is constructed with a single finger for each channel. For the droplet ejection it is essential to have a nozzle plate with nozzles of conical shape for each channel or a combination of nozzle plate and nozzle foil.

Figure 3 shows the cross section of the printhead demonstrating the structure of the piezoelectric fingers called ‘paddles’. The upper part of the actuator element is made of active piezoceramic material built in several layers of 20 µm thickness. Between the polarised ceramic layers there are electrodes combined and connected to the driving electronics. The piezo fingers have to be passivated providing a chemical and electronical protection against the corrosive and conductive ink.

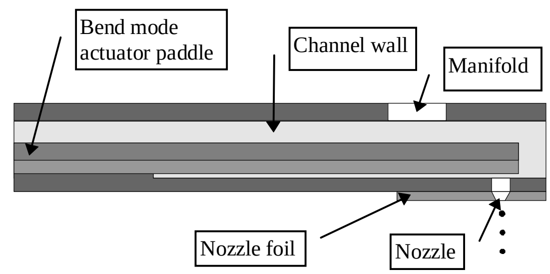

Figure 3.Cross section of a bend mode actuator piezo printhead

The distance between the channel wall and the piezo finger as well between the piezo finger and the nozzle are substantial for the performance of the printhead. Therefore, a high aspect ratio of the wall has to be chosen to ensure smooth piezo finger movements along the walls.

Function principle

In the case of a bend mode printhead, the actuator owns a bimorph structure consisting of an active and a passive layer. If a voltage is applied to the multilayer ceramic, the single active layer will change its thickness according to the inverse piezo effect. Thus, the whole active part of the actuator shrinks. The passive part keeps

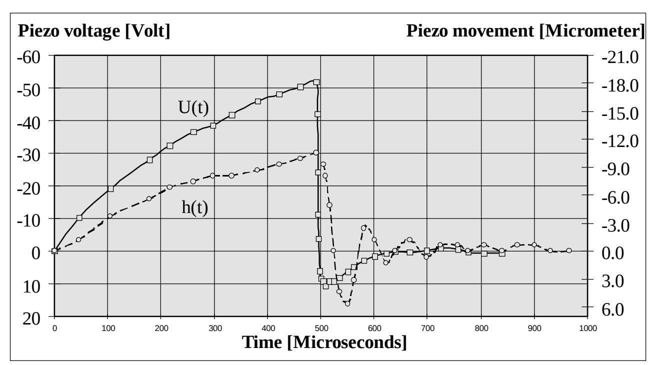

Figure 4: Voltage and movement of the piezo

its geometry resulting in a bending movement of the actuator. If the voltage is switched to zero by discharging, the actuator recovers to the original position inducing a droplet ejection. The actuator is fixed at one end while the other end is moving up and down towards the nozzle.

By applying a suitable pulse shape at the piezo finger, a droplet is ejected as depicted in Figure 4 where the voltage at the piezo element and the measured movement of the piezo finger have been investigated.

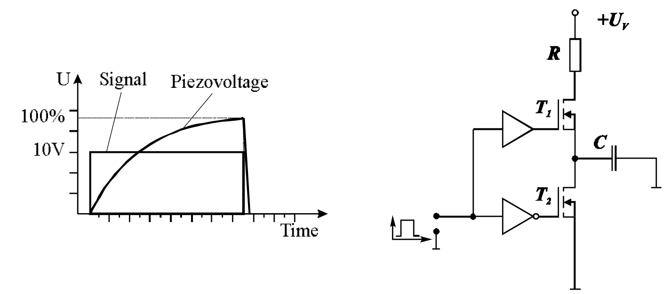

Figure 5: Drive electronics for a bend mode actuator printhead

The displayed pulse shape can be created by a simple electronic circuit (Figure 5) where T_1 and T_2 are transistors. During applying a positive pulse the piezo C is loaded with a currency limited by resistor R and the supply voltage U_v. At the end of the pulse T_2 will deload the piezo instantly.

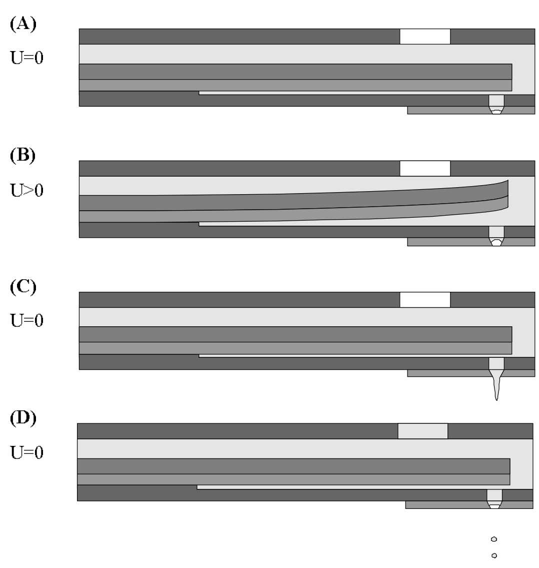

Figure 6: Droplet ejection process

Figure 6 demonstrates the sequence of a droplet ejection. In (A) the actuator is in the stand-by position where no voltage is applied. The ink reservoir produces a small backpressure in the ink chamber. In (B) a voltage in the direction of the polarization is applied which results in a contraction of the active layers perpendicular to the electric field. The actuator bends relatively slowly as displayed in the picture. For the ejection of the droplet the piezo capacitor C has to be discharged very fast. The piezo paddle recedes very quickly to the original position and leads to the droplet ejection (C). Immediately after that the ink channel is refilled as a consequence of capillary forces (D).

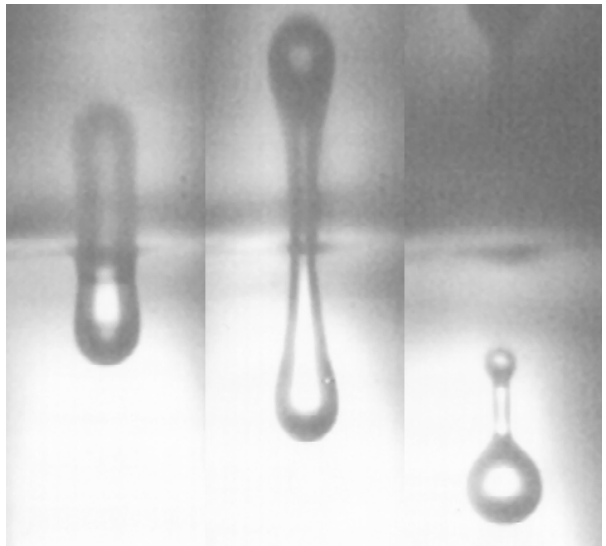

Figure 7: Droplet ejection of a bend mode printhead

The basic principle of the droplet ejection is very simple and straight forward. An example of an ejected droplet is shown in Figure 7. For this experiment diethyl succinate with a density of 1040 g l^{-1}, a dynamic viscosity of 2.9 mPa s and a surface tension of 35 mN m^{-1} was used. The supply voltage was 50 Volt and stable droplet ejection was received up to 10 kHz. All the measurements were conducted with handmade prototypes (Figure 8). Using better nozzle qualities and an optimized printhead design, much better results are likely to be received.

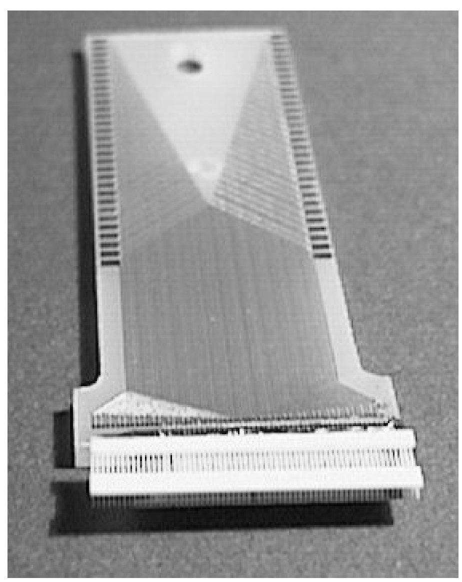

Figure 8: Prototype of a bend mode actuator printhead

Advantages of the bend mode printhead

The bend mode actuator printhead has a lot of advantages such as much simpler working principle compared with many other printhead designs leading to lower production costs.

Another benefit is that the droplet ejection is maintained by the use of a volume effect. This means that the acoustics of the channel plays no important role during droplet ejection like in other standard piezo printheads. This results in a very robust working performance combined with a high bubble tolerance. An air bubble in the printhead channel is fatal for a typical piezo printhead while the bending actuator printhead is more tolerant. In case of running out of ink, air bubbles will enter the printhead. The bend mode printhead just continues to work without flushing the whole printhead by simply supplying new ink because the space between the piezo finger and the nozzle is so small that any air bubble is pushed away into the room above the paddle.

An additional advantage of the printhead is the simple driving pulse shape which reduces costs for the electronic circuitry. Furthermore, the printhead can be used for a wide range of different fluids and dynamic viscosities. The operational window of the viscosity lies between 0.7 and 20 mPa s. Another benefit is that the paddle printhead allows high working frequencies, e.g. in the existing design the eigenfrequency of the piezo actuator in the fluid is 12.2 kHz. With this set-up it was possible to reach a stable droplet frequency of up to 10 kHz. If required, the printhead design can be easily adjusted to higher frequencies.

Advantageous is also that in the case of the bending mode printhead the simultaneous firing of all channels is possible. Thus, the function principle requires no further tilting of the printhead, as compensation for a multiplexed printhead firing, as many other piezo designs [4].

Spray design

As already mentioned, the previous described technology is applicable to a wide range of areas not necessarily only used as printing device. For many other applications an exact placement of the droplet with a well-defined drop velocity and volume is not essential because it is sufficient to have a device which simply sprays a special fluid.

Figure 9 displays a device used as a sprayer. For that purpose, the well-designed walls are not necessary. Instead of using single piezo paddle fingers, the piezo bend mode actuator is constructed as one plate. In order to get a high volume flow there are several nozzles below the piezo actuator necessary resulting in various ejected droplets by applying only one pulse. With this procedure, it is possible to get a defined volume range and velocity distribution of the droplets. The function principle and modeling of such a piezo paddle micro pump has been described by Ederer [5, 6].

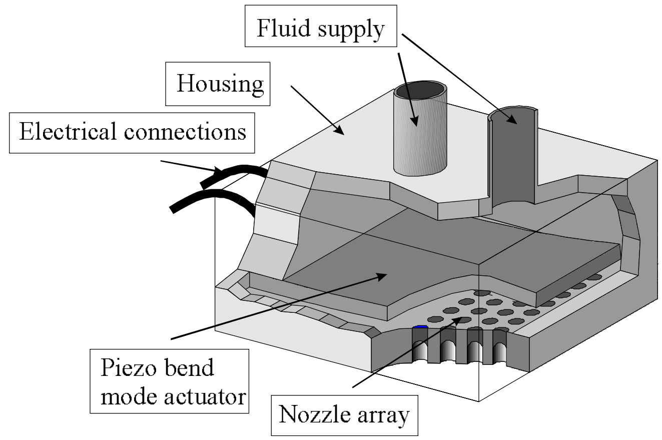

Figure 9: Sprayer based on a bend mode actuator

Areas of applications

The spray design of the bend mode actuator printhead has many potential applications such as in the area of medical care as inhalator. In this case the nozzles are creating small droplets of a medicine.

Prototypes of these printheads were also used for the dispersion of fuel. The small droplets can be easily lighted and the printhead works in that case like a burner for a heater (Figure 10). Several tests have shown that this design of a burner has a high efficiency and lifetime.

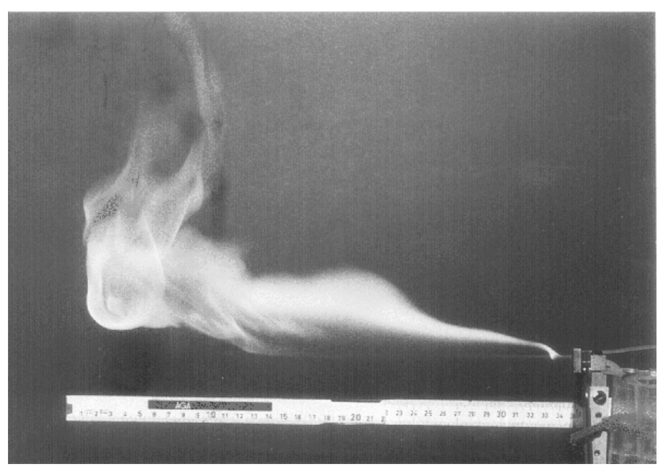

Figure 10: Sprayer as Flame generator

The mass flow produced with such a head is up to 12 ml min^{-1}. In all of these applications the robust behavior of the printhead plays a major role. This shows that the bend mode principle with its tolerance against air bubbles is magnificent for many thinkable requirements were spraying or printing of different fluids is necessary.

Conclusion

The bend mode actuator principle together with modern production technologies is a competitive design for an inkjet printhead. Moreover, the robust behavior of these printheads enhances the wide range of applications concerning the fluids as well as the technology itself.

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Biography

Mr. Kretschmer is manager of Inkjet Technology at Pelikan Produktions AG, Egg. He joined the company in May 1993 and is involved in new product development, test infrastructure, analysis, product and print quality and is leading projects in the field of printhead development and application.

He previously worked for four years at Mannesmann Tally, Germany, an important printer manufacturer. During this time he gained experience in inkjet printing and electrophotography.

As a physicist, he received his diploma at the University of Ulm, Germany. Mr. Kretschmer is author of several patent applications and publications in the field of inkjet and electrophotography.