The Application of the Inkjet Technology in Capsule Endoscope

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Abstract

The wireless capsule would have been more comfortable for the patients than the traditional endoscope. The wireless capsules, such as Heidelberg capsule, pH capsule or the M2A capsule, just would be the diagnostic tool. However, the M2A capsule only uses as the image sensor to find the nidus. It only sends the image data to the record outside the body. If the capsule could take the drugs to the intestine and jet to the nidus, it would reduce the pains of the patient. The advantage of the ink-jet technology is jet liquid to the target quantitatively and accurately. The present would show the inkjet technology applied on the capsule endoscope system which also includes the imager, illumination source, microlens, two-way wireless module. There are ink-jet type micro actuator, medicine tank, and control circuit in the medicine-jet subsystem. The micro actuator can jet medicine droplets by the droplet-on-demand. The droplet volume could be few Pico-liters. Since the characteristic of the ink-jet technology, the medicine could be put in the medicine tank of the swallow capsule, brought to the ridus and jetted.

Introduction

In the medical field, several types of miniaturized wireless capsules have been used, such as M2A capsule endoscopes that can take pH, temperature, motility and pressure measurement in the intestine and send biomedical video signal or measured data from inside the human body.[1] The capsule, about 11mm in diameter and 30mm in longitude, i.e. about the size of a pill, provides a kind of inside view at a rate of two frames per second. Its video images are transmitted by using UHF-band RF to eliminate the problems related to fiber-optical endoscopes. This development of miniaturized capsule is expected to eliminate patient discomfort and the limitations into the small bowel which general over 6m. However, such the M2A capsule only has used as the image sensor to find the nidus which has taken the image data and send to the record outside the body. If the capsule could take the drugs to the intestine and jet to the nidus, it would reduce the pains of the patient.

The present paper would show the inkjet technology applied on the capsule endoscope.

There are many methods for the release of the drugs in capsule. The first type is the pressure feed. The pressure feed type uses a pressured tank which stores high pressure than that outside capsule. The drugs could be discharged from the drug tank by the high pressure gas. The discharged drugs would form a drug spray. The cone angle of the spray would be form a larger cap area which is better in therapy. However, some drugs would squander because discharged outside the nidus. So, the mainly disadvantage of the pressure feed type is the accuracy of the drug delivery.

The advantage of the inkjet type is the accuracy of the position and quantity of the drugs delivery. The principle of the inkjet technology is transferred the electronic energy to the kinetic energy for discharging the liquid out of the nozzle. The liquid out of the nozzle would form a single drop for the liquid properties such as viscosity and surface tension. There are two type of the inkjet actuator, continue and drop-on-demand.

The advantages of the drop-on-demand (DOD) type are micro quality and position. It only needs the electronic signal from the control circuit on the main board which includes the control of the CCD, RF and LEDs. The integration of these subsystems, CCD, RF, LEDs and drug micro actuator would be possibility for the medicine-jet capsule endoscope.

The Description of the System

This paper would show the mainly subsystems of the medicine-jet capsule endoscope, that is, drug micro actuator and bi-direction RF. Firstly, the drug micro actuator would be tiny, it could be fabricated by MEMS procedure.

Design of the Drug Micro Actuator

On the basis of the medicine-jet subsystem could be put in the swallow capsule, the capsule is 11mm in diameter and 30mm in longitude. The design limitations corresponding to the micro actuator subsystem are as follows:

- Low power consumption
- Miniaturization
- Integrated fabrication

A variety of micro actuator have been developed and demonstrated including membrane pumps,[2-4] electro-hydrodynamic pumps,[5,6] bubble pumps,[7] diffuser pump[8] and electro-capillary pumps.[9] Among these actuator, bubble actuator can be easily generated by resistive heaters and can be applied to nonspecific liquids, thus is an attractive actuation source in the micro scale.[10]

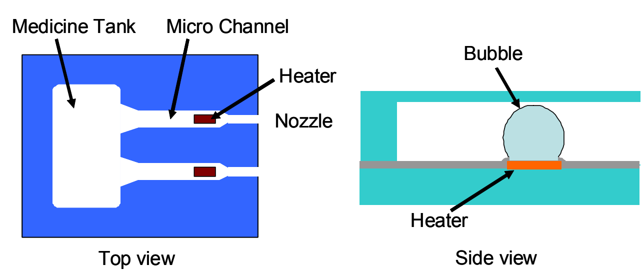

Figure 1. Schematic drawing of Micro medicine jet

In this study, we attempted to integrate thermal-bubble micro actuator and hydrophobic valve by MEMS technology. There are ink-jet type micro actuator and medicine tank in the micro medicine jet. The advantage of the ink-jet technology is discharge liquid to the target quantitatively and accurately. The micro actuator can discharge medicine droplets by the droplet-on-demand. The droplet volume could be the picoliter order.

Figure 1 shows the schematic view of drug micro actuator. It consists of a medicine tank, heaters, micro channels and nozzles. Medicine is fed to each channel from the medicine tank of chip. Each heater is located on each channel. Nozzles are formed at the right side of chip. Once heater is activated by pulse voltage, a bubble expands in shapes with the heater, followed by injection of a drug droplet from the channel. Drug is fed by capillary force to each channel for next ejection.

Fabrication of the Drug Micro Actuator

In the fabrication process, the chip contains upper plate and lower plate. Upper plate includes micro channel, chamber and nozzle; Lower plate includes heater and conductor. Finally, upper plate and lower plate are aligned and bonded together. The structure of upper plate and lower plate has different fabrication process; a brief summary of fabrication is described individually.

The fabrication process of lower plate is illustrated in Figure 2. First, the glass substrate is defined the heater layer by using photoresist lithography in Figure 2(b). After deposited the metal layer about 1000Å in thick as heater and the photoresist is removed. Then, another metal is deposited about 1500Å in thick as protection layer shown in Figure 2(e). A new photoresist layer is applied and the lithography for conductor line is performed. The uncovered seed layer is etched and the photoresist is removed to form conductor line as shown in Figure 2(g).

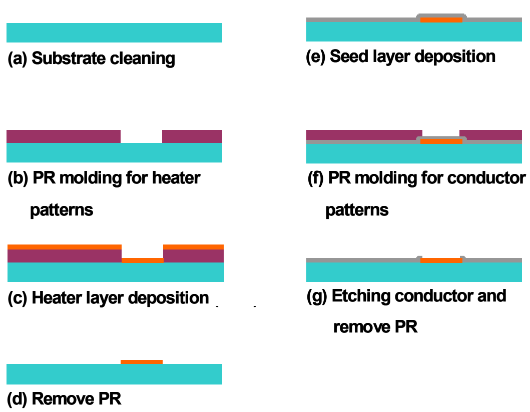

Figure 2. Lower plate fabrication process

Upper plate uses PDMS fabrication process to form micro channel, chamber and nozzle. In the PDMS fabrication process, standard lithography technology is used to form SU-8 templates with inverse images of structures. SU-8 negative thick film photoresist remains structurally stable after lithography. The fabrication process is illustrated in Figure 3. A polished silicon substrate is spin-coated with a layer of SU-8 structure and the lithography for the SU-8 structured molds is performed as shown in Figure 3(b).

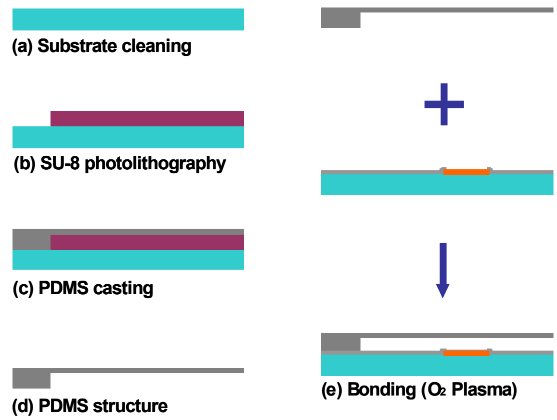

Figure 3. PDMS fabrication process

The next procedure is the fabrication of PDMS structure. Silicone elastomer and elastomer curing agent at appropriate weight ratio are thoroughly mixed together. Then, PDMS is spin-coated onto the SU-8 mold and baked at low temperature on hardened shapeable elastic material as shown in Figure 3(c). The solidified PDMS chip structure is demoded from the mold as shown in Figure 3(d). Finally, upper plate and lower plate are aligned and bonded by using oxygen plasma for surface treatment as shown in Figure 3(e).

Image Sensor and RF Transceiver

Imager Subsystem and Wireless Subsystem

The imager includes light sources, micro-lens, image sensor, encoding module and receiving module. The goal of the subsystem is to take the image from the image sensor. The light source could supply the light to illuminate the inner surface of the digestive tract and the micro-lens then focuses the reflected light onto the image sensor. Since the image signal from image sensor would be a large bitmaps, the encoding procedure could be necessary. The current method presents the design of one bi-directional wireless system, which can transmit video images to the external receiving system and also receive medicine-jet signals from an external trigger system (e.g.: PC with DIO card, digital input and output card). The schematic diagram of the subsystem, which includes wireless subsystem, is shown in Figure 4.

This proposed schematic diagram includes an image sensor, a medicine-jet module, two RF modules, two antennas and one PC with DIO card.

At first, the image sensor can capture images of internal organs and transmit the images to RF module_1. The images are transmitted from RF module_1 to RF module_2. Then, the PC with DIO card receives the images from RF module_2 and shows them on the monitor. If the image of internal organs hurt is detected, the medicine-jet signal will be send out from the PC with DIO card. The medicine-jet signal is transmitted from RF module_2 to RF module_1. Finally, the medicine-jet module receives the medicine-jet signal from RF module_1 to heal the wound.

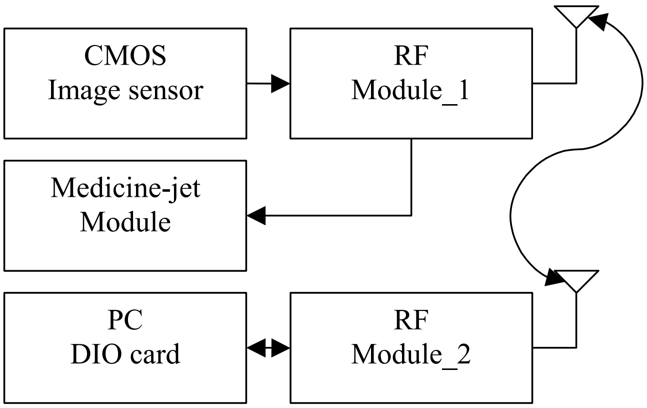

Figure 4. The schematic diagram of the imager and wireless subsystem

The image sensor is a color digital CMOS (complementary metal-oxide semiconductor) image sensor with resolution of 164 (H) x 124 (V). It outputs 8, 4, 2 or 1-bit digital raw data or 8-bit formatted data per pixel. The image sensor performs automatic gain control, automatic exposure control, and automatic de-flicker. The RF module is a true single chip system with fully integrated RF transceiver, 8051 compatible microcontroller and 4 input AD convert. The circuit has embedded voltage regulators, which provides maximum noise immunity and allows operation on a single 1.9V to 3.6V supply.

Experimental

For the prototype fabrication, the drug micro actuators are fabricating. The application of the inkjet technology in drug delivery would shown by inkjet cartridge. Figure 5 shows the epinephrine had discharged from inkjet cartridge. The structure of the inkjet cartridge is similar with the design of the paper. The epinephrine would be filled in the ink storage of the cartridge and jetted out. However, it does not like ink or water. The therapy effect of the epinephrine would remain after discharged out of the cartridge.

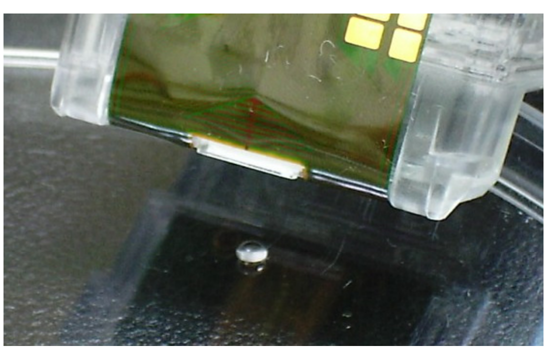

Figure 5.The epinephrine jetted onto subtract

Conclusion

Since the advantage of the inkjet technology, the drug micro actuator would be integrated with other subsystem into capsule. The drug micro actuator could discharge micro medicine droplets by bi-direction wireless control. The fabrication of the micro actuator is an easy process of the MEMS. So, it would reduce the manufacturing cost. This paper also shows the bi-direction wireless subsystem, it is important for the drug micro actuator. The medicine jet signal would be sent to the actuator to discharge drug drops after the nidus discovered through the image sensor, wireless transmitter by observatory. This system will reduce the pains of the patients largely and rapidly.

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Ching-Long Chiu joined the Printing Technology Division of OES/ITRI in 1998. He received his M.S. and Ph.D from Institute of Aeronautical and Astronautical Engineering of National Cheng Kung University. His interest lies in the field of computational fluid dynamics, application of the inkjet technology. He now is the engineer of the 3D-jet Laboratory in OEAC/ITRI.

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