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Bhawna Poudyal
Department of Pharmaceutics, Kr College of Pharmacy Bengaluru, Rajiv Gandhi University of Health Science Karnataka, Bengaluru, Diploma in Pharmacy "Himalayan Pharmacy Institute, East Sikkim, Sikkim, India

Correspondence
Bhawna Poudyal
Department of Pharmaceutics, Kr College of Pharmacy Bengaluru, Rajiv Gandhi University of Health Science Karnataka, Bengaluru, Diploma in Pharmacy "Himalayan Pharmacy Institute, East Sikkim, Sikkim, India

Electronic pill

Bhawna Poudyal

Abstract
Combination of biology and electronics has led to many new inventions. These are useful to combat deadly diseases. One such invention is microelectronic pill. This phenomenon is used to detect diseases and abnormalities in the body. This is an indigestible pill and comprises of sensors. These sensors measure various body parameters like pH of stomach acid and intestinal. There is an integrated circuit which controls the sensors. There are in all four sensors. These measure temperatures and dissolved oxygen. These sensors are mounted on top of two silicon chips. The microelectronic pill is completely harm-free to the body.
There is a radio transmitter to transmit the signals from the sensors. The data are transmitted to a nearby receiver where it is converted to the desired form for analysis. There is a chemical coating on top of the arrangement. This unit is powered by a Ag2O battery which has operating time of about 35 hours. The chip is highly adaptive in nature and can be used in various biomedical and industrial applications. These chips can be used for quick detection of complex diseases which would otherwise take a long time. Many gastrointestinal diseases can be detected using this terminology. It is especially used in cases where it is not easy to get a sample for analysis.

Keywords: Micro electronic, pill, biosensors, chip

1. Introduction
We are familiar with a wide range of sensors in the field of electronics. They are used widely in the various experiments and research activities too. This microelectronic pill is such a sensor with a number of channels and is called as a multichannel sensor. As the name implies this sensor is a pill. That is it is meant to go inside the body and to study the internal conditions.
Earlier it was when transistor was invented, that radiometry capsules were first put into use. These capsules made use of simple circuits for studying the gastrointestinal tract. Some of the reasons that prevented their use was their size and their limitation of not to transmit through more than a single channel. They had poor reliability and sensitivity. The lifespan of the sensors were also too short. This paved the way for the implementation of single channel telemetry capsules and they were later developed to overcome the demerits of the large size of laboratory type sensors. The semiconductor technologies also helped in the formation and thus finally the presently seen microelectronic pill was developed.
These pills are now used for taking remote biomedical measurements in researches and diagnosis. The sensors make use of the micro technology to serve the purpose. The main intention of using the pill is to perform an internal study and recognize or detect the abnormalities and the diseases in the gastrointestinal tract. In this GI (gastrointestinal) tract we cannot use the old endoscope as the access is restricted. A number of parameters can be possibly measured by these pills and they include conductivity, pH temperature and the amount of dissolved oxygen in the gastrointestinal tract.

2. Microelectronic Pill
The design of the microelectronic pill is in the form of a capsule. The encasing it has is biocompatible. Inside this are multi- channel (four channel) sensors and a control chip. It also comprises of a radio transmitter and two silver oxide cells. The four sensors are mounted on the two silicon chips. In addition to it, there are a control chip, one access channel and a radio transmitter. The four sensors commonly used are a temperature sensor, pH ISFET sensor, a dual electrode conductivity sensor and a three electrode electrochemical oxygen sensor. Among these the temperature sensor, the pH ISFET sensor and the dual electrode conductivity sensor are fabricated on the first chip. The three electrode electrochemical cell oxygen sensor will be on chip 2. The second chip also consists of a NiCr resistance thermometer which is optional.

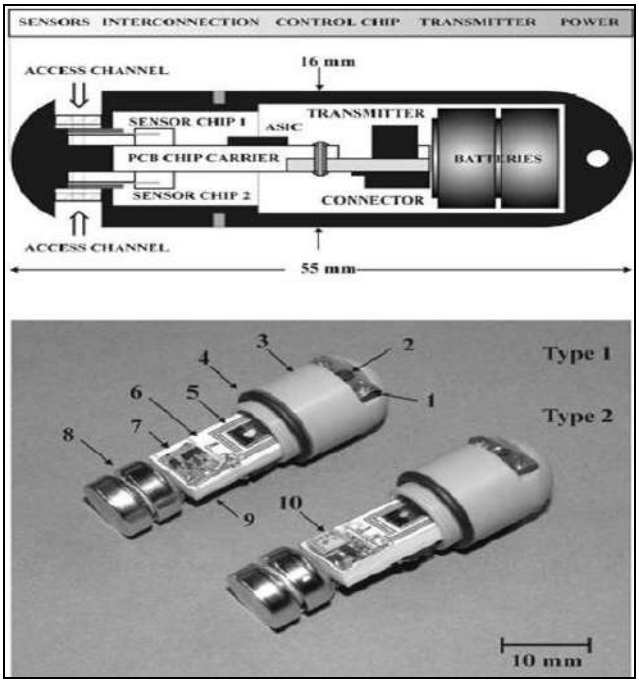

Fig 1: block diagram

Microelectronic pill consists of 4 sensors (2) which are mounted on two silicon chips (Chip 1 & 2), a control chip (5), a radio transmitter (STD- type 1-7, type2-crystal type-10) & silver oxide batteries (8).
1-access channel, 3-capsule, 4- rubber ring, 6-PCB chip carrier

Basic Components

A. Sensors

There are basically 4 sensors mounted on two chips- Chip 1 & chip 2. On chip 1 temperature sensor silicon diode (4), pH ISFET sensor (1) and dual electrode conductivity sensor (3) are fabricated. Chip 2 comprises of three electrode electrochemical cell oxygen sensor (2) and optional NiCr resistance thermometer.

1) Sensorchip1

An array consisting of both temperature sensor & pH sensor platforms were cut from the wafer & attached onto 100-µm-thick glass cover slip cured on a hot plate. The plate acts as a temporary carrier to assist handling of the device during level 1 of lithography when the electric connections tracks, electrodes bonding pads are defined. Bonding pads provide electrical contact to the external electronic circuit.
Lithography was the first fundamentally new printing technology since the invention of relief printing in the fifteenth century. It is a mechanical Plano graphic process in which the printing and non-printing areas of the plate are all at the same level, as opposed to intaglio and relief processes in which the design is cut into the printing block. Lithography is based on the chemical repellence of oil and water. Designs are drawn or painted with greasy ink or crayons on specially prepared limestone. The stone is moistened with water, which the stone accepts in areas not covered by the crayon. Oily ink, applied with a roller, adheres only to the drawing and is repelled by the wet parts of the stone. Pressing paper against the inked drawing then makes the print.
Lithography was invented by Alois Seinfeld in Germany in 1798 and, within twenty years, appeared in England and the United States. Almost immediately, attempts were made to print pictures in color. Multiple stones were used; one for each color, and the print went through the press as many times as there were stones. The problem for the printers was keeping the image in register, making sure that the print would be lined up exactly each time it went through the press so that each color would be in the correct position and the overlaying colors would merge correctly.
Early colored lithographs used one or two colors to tint the entire plate and create a watercolor-like tone to the image. This atmospheric effect was primarily used for landscape or topographical illustrations. For more detailed coloration, artists continued to rely on hand coloring over the lithograph. Once tinted lithographs were well established, it was only a small step to extend the range of color by the use of multiple tint blocks printed in succession. Generally, these early chromolithographs were simple prints with flat areas of color, printed side-by-side.

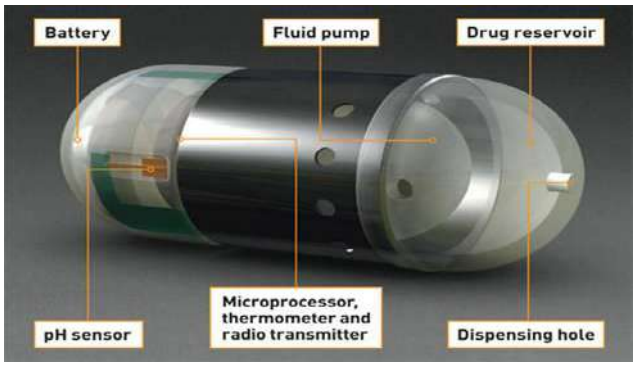

Fig 2: Pill

Increasingly ornate designs and dozens of bright, often gaudy, colors characterized chromolithography in the second half of the nineteenth century. Overprinting and the use of silver and gold inks widened the range of colour and design. Still a relatively expensive process, chromolithography was used for large-scale folio works and illuminated gift books that often attempted to reproduce the handwork of manuscripts of the Middle Ages. The steam-driven printing press and the wider availability of inexpensive paper stock lowered production costs and made chromolithography more affordable. By the 1880s, the process was widely used for magazines and advertising. At the same time, however, photographic processes were being developed that would replace lithography by the beginning of the twentieth century.

2) Sensor Chip 2

The level 1pattern (electric tracks, bonding pads, and electrodes) was defined in 0.9µm UV3 resist (Shipley, U.K.) by electron beam lithography. A layer of200 nm gold (including an adhesion layer of 15 nm titanium and 15 nm palladium) was deposited by thermal evaporation. The fabrication process was repeated (Level 2) to define the5-m-wide and 11-mm-long NiCr resistance thermometer made from a 100-nm-thick layer of NiCr (30-resistance). Level 3 defined the 500-nm-thick layer of thermal evaporated silver used to fabricate the reference electrode. An additional sacrificial layer of titanium (20 nm) protected the silver from oxidation in subsequent fabrication levels. The surface area Fig. 2. Photograph of the 4:75 2 4:75 mm application specific integrated circuit control chip (a), the associated

explanatory diagram (b), and a schematic of the reference electrode was 1.5*10^-2 mm, whereas the of the architecture (c) illustrating the interface to external components. MUX counter electrode made of gold had an area of mm. (four-channel multiplexer), ADC, DAC, and OSC (32-kHz oscillator). Level 4 defined the microelectrode array of the working electrode, comprising 57 circular gold electrodes, each 10µm in diameter, with an inter electrode spacing of 25 m and a combined area of 4.5*10^-3 mm. Such an array promotes electrode polarization and reduces response time by enhancing transport to the electrode surface [26]. The whole wafer was covered with 500 nm plasma-enhanced chemical vapor deposited (PECVD) Si3Ni4 The pads, counter, reference, and the microelectrode array of the working electrode was exposed using an etching mask of S1818 photo resist prior to dry etching with C2F6. The chips were then diced from the wafer and attached to separate100- m-thick cover slips by epoxy resin to assist handling. The electrolyte chamber was defined in 50- m-thick polyimide at Level 5.

Residual polyimide was removed in a barrel a shear (2 min), prior to removal of the sacrificial titanium layer at Level6 in a diluted HF solution (HF to RO water, 1:26) for 15 s. The short exposure to HF prevented damage to the PECVD layer. Thermally evaporated silver was oxidized to Ag AgCl (50% of film thickness) by chronopotentiometry (120 nA, 300 s) at Level 7 in the presence of KCl, prior to injection of the internal reference electrolyte at Level 8.

A. sheet of oxygen

5*5mm sheet of oxygen permeable Teflon was cut out from a 12.5- m-thick film and attached to the chip at Level 9 with epoxy resin prior to immobilization by the aid of a stainless-steel clamp.

B. Control Chip

The ASIC was a control unit that connected together the external components of the micro system It was fabricated as a 22.5 mm silicon die using a 3-V, 2-poly, 3-metal 0.6µM

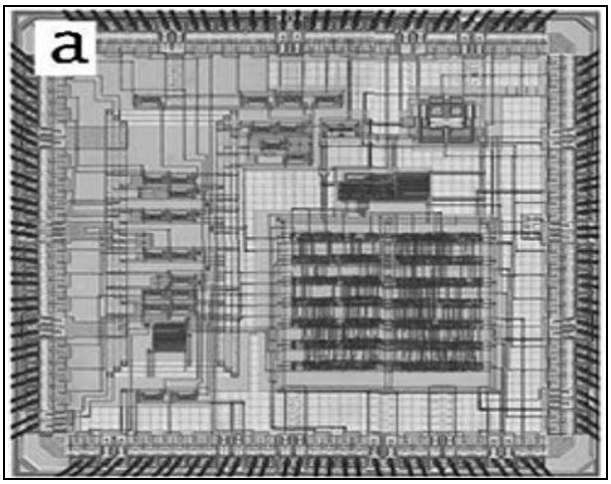

Fig 3: the associated explanatory diagram of 4:75 2 4:75 mm application specific integrated circuit control chip

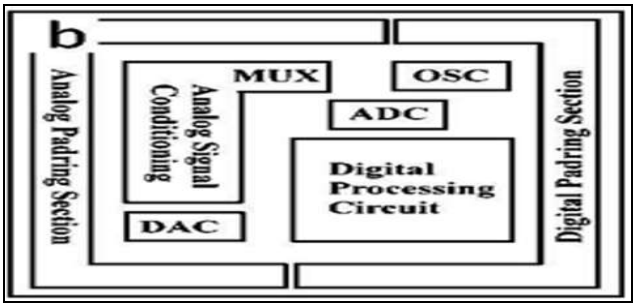

Fig 4: Schematic of the architecture

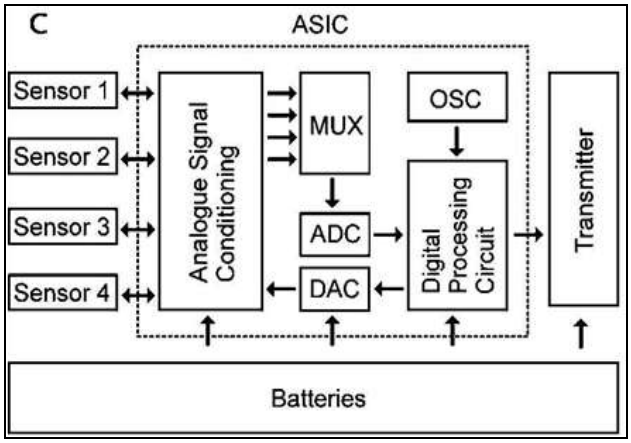

Fig 5: Illustrating the interface to external components is particularly effective.

When the measuring environment is acquiescent, a condition encountered in many applications the entire design was constructed with a focus on low power consumption and immunity from noise interference. The digital module was deliberately clocked at 32 kHz and employed a sleep mode to conserve power from the analogue module. Separate on-chip power supply trees and pad-ring segments were used for the analogue and digital electronics sections in order to discourage noise propagation and interference.

C. Radio Transmitter

The radio transmitter was assembled prior to integration in the capsule using discrete surface mount components on a single-sided printed circuit board (PCB). The footprint of the standard transmitter measured 8*5*3mm including the integrated coil (magnetic) antenna. It was designed to operate at a trans-mission frequency of 40.01 MHz at 20 C generating a signal of 10 kHz bandwidth. A second crystal stabilized transmitter was also used. This second unit was similar to the free running standard transmitter, apart from having a larger footprint of 10*5*3mm, and a transmission frequency limited to 20.08MHz at 20 C, due to the crystal used. Pills incorporating the standard transmitter were denoted Type I, whereas the pills in-cooperating the crystal stabilized unit were denoted Type II. The transmission range was measured as being 1 meter and the modulation scheme frequency shift keying (FSK), with a data rate of1Kbs^-1.

D. Capsule

The microelectronic pill consisted of a machined biocompatible (noncytotoxic), chemically resistant polyetherterket one (PEEK) capsule (Victrix, U.K.) and a PCB chip carrier acting as a common platform for attachment of the sensors, ASIC, transmitter and the batteries (Fig. 3). The fabricated sensors were each attached by wire bonding to a custom-made chip carrier made from a 10-pin, 0.5-mm pitch polyimide ribbon connector. The ribbon connector was, in turn, connected to an industrial standard 10-pin flat cable plug (FCP) socket (Radio Spares, U.K.) attached to the PCB chip carrier of the microelectronic pill, to facilitate rapid replacement of the sensors when required. The PCB chip carrier was made from two standard1.6-mm-thick fiber glass boards attached back-to-back by epoxy resin which maximized the distance between the two sensor chips. The sensor chips were connected to both sides of the PCB by separate FCP sockets, with sensor Chip 1 facing the top face, with Chip 2 facing down. Thus, the oxygen sensor on Chip 2 had to be connected to the top face by three 200- m copper leads soldered on to the board. The transmitter was integrated in the PCB which also incorporated the power supply rails, the connection points to the sensors, as well as the transmitter and the ASIC and the supporting slots for the capsule in which the chip carrier was located. The ASIC was attached with double-sided copper conducting tape (Agar Scientific, U.K.) prior to wire bonding to the power supply rails, the sensor inputs, and the transmitter (a process which entailed the connection of 64 bonding pads). The unit was powered by two standard 1.55-V SR44 silver oxide cells with a capacity of 175 mAh. The batteries were serial connected and attached to a custom made 3-pin, 1.27-mm pitch plug well as making it easy to maintain (e.g., during sensor and battery replacement). The complete prototype was 16.55 mm and weighted 13.5 g including the batteries. A smaller pill suitable for physiological in vivo trials (1030 mm) is currently being developed from the prototype.

3. Material and Methods

General Experimental Setup

All the devices were powered by batteries in order to demonstrate the concept of utilizing the microelectronic pill in remote locations (extending the range of applications from in vivo sensing to environmental or industrial monitoring). The pill was submerged in a 250-mL glass bottle located within a 2000-mLbeaker to allow for a rapid change of pH and temperature of the solution. A scanning receiver (Win radio Communications, Australia) captured the wireless radio transmitted signal from the microelectronic pill by using a coil antenna wrapped around the 2000-polypropylene beaker in which the pill was located. A portable Pentium III computer controlled the data acquisition unit (National Instruments, Austin, TX) which digitally acquired analogue data from the scanning receiver prior to recording it on the computer. The solution volume used in all experiments was 250 mL the beaker, pill, glass bottle, and antenna were located within 25*25 cm container of polystyrene, reducing temperature fluctuations from the ambient environment (as might be expected within the GI tract) and as required to maintain a stable transmission frequency. The data was acquired using Lab View (National Instruments, Austin, TX) and processed using a MATLAB (Math works, Natick, MA) routine.

Sensor Characterization

The lifetime of the incorporated AgCl reference electrodes used in the pH and oxygen sensors was measured with an applied current of 1 PA immersed in a 1.0 M KCl electrolyte solution. The current reflects the bias input current of the operational amplifier in the analogue sensor control circuitry to which the electrodes were connected the temperature sensor was calibrated with the pill submerged in reverse osmosis (RO) water at different temperatures. The average temperature distribution over 10 min was recorded for each measurement, represented as 9.1 C, 21.2 C, 33.5C, and 47.9 C.

The system was allowed to temperature equilibrate for 5 min prior to data acquisition. The control readings were performed with a thin wire K-type thermocouple (Radio Spares, U.K.). The signal from the temperature sensor as investigated with respect to supply voltage potential, due to the temperature circuitry being referenced to the negative supply rail. Temperature compensated readings (normalized to23 C) were recorded at a supply voltage potential of 3.123, 3.094, 3.071, and 2.983 mV using a direct communication link. Bench testing of the temperature sensor from 0 C to 70 C was also performed to investigate the linear response characteristics of the temperature sensor. The pH sensor of the microelectronic pill was calibrated in standard pH buffers [28] of pH 2, 4, 7, 9, and 13, which reflected the dynamic range of the sensor. The calibration was performed at room temperature (23 C) over a period of 10 min, with the CMOS process by Austria Microsystems (AMS) via the Euro practice initiative It is a novel mixed signal design that contains an analogue signal conditioning module operating the sensors, an 10-bit analogue-to-digital (ADC) and digital-to-analogue (DAC) converters, and a digital data processing module. An RC relaxation oscillator (OSC) provides the clock signal. The analogue module was based on the AMS OP05B operational amplifier, which offered a combination of both a power having scheme (sleep mode) and a compact integrated circuit design. The temperature circuitry biased the diode at constant current, so that a change in temperature would reflect a corresponding change in the diode voltage. The pH ISFET sensor was biased as a simple source and drain follower at constant current with the drain-source voltage changing with the threshold voltage and ph. The conductivity circuit operated at direct current measuring the resistance across the electrode pair as an inverse function of solution conductivity. An incorporated potential at circuit operated the amperometry oxygen sensor with a10-bit DAC controlling the working electrode potential with respect to the reference. The analogue signals had a full-scale dynamic range of 2.8 V (with respect to a 3.1-V supply rail) with the resolution determined by the ADC. The analogue signals were sequenced through a multiplexer prior to being digitized by the ADC. The bandwidth for each channel was limited by the sampling interval of 0.2 Ms.

The digital data processing module conditioned the digitized signals through the use of a serial bit stream data compression algorithm, which decided when transmission was required by comparing the most recent sample with the previous sampled data. This technique minimizes the transmission length, and comprising the electronic pill. The prototype is 16 2 55 mm, weights 13.5 g. The Type I unit consist of the microelectronic sensors at the front enclosed by the metal clamp and rubber seal (1) which provide a 3-

mm-diameter access channel to the sensors (2). The front section of the capsule, physically machined from solid PEEK, is illustrated (3) with the rear section removed to illustrate the internal design. The front and rear section of the capsule is joined by a screw connection sealed of by a Viton-rubber O-ring (4). The ASIC control chip (5) is integrated on the common PCB chip carrier (6) which incorporate the discrete component radio transmitter, and the silver oxide battery cells. The battery is connected on the reverse side of the PCB (9). The Type II unit is identical to the Type I with exception of an incorporated crystal stabilized radio transmitter for improved temperature stability. By electrical conducting epoxy (Centronics, Kennesaw, GA). The connection to the matching socket on the PCB carrier provided a three-point power supply to the circuit comprising a negative supply rail (1.55 V), virtual ground (0 V), and a positive supply rail (1.55 V). The battery pack was easily replaced during the experimental procedures. The capsule was machined as two separate screw-fitting compartments. The PCB chip carrier was attached to the front section of the capsule. The sensor chips were exposed to the ambient environment through access ports and were sealed by two sets of stainless-steel clamps incorporating a 0.8-mthick sheet of Viton fluor elastomer seal. A 3-mm-diameter access channel in the center of each of the steel clamps (incl. the seal), exposed the sensing regions of the chips. The rear section of the capsule was attached to the front section by a 13-mmscrew connection incorporating a Viton rubber O-ring (James Walker, U.K.). The seals rendered the capsule water proof, as pill being washed in RO water between each step. A standard lab pH electrode was used as a reference to monitor the pH of the solutions (Consort n.v., Belgium).

The pH channel of the pill was allowed to equilibrate for 5 min prior to starting the data acquisition. Each measurement was performed twice. Bench test measurements from pH 1 to 13 were also performed using an identical control circuit to the ASIC. The oxygen sensor was bench tested with a standard laboratory potentiated (Bio analytical Systems, West Lafayette, IN), over its dynamic range in phosphate buffered saline (PBS) using a direct communication link at 23 C. Cyclic voltammetry within sweep potential from 0.1 to 0.45 V (versus Ag AgCl) was performed in 1-mM ferroscene-monocarboxylic acid (FMCA) as model redox compound, to test the performance of the micro-electrode array. A three-point calibration routine was performed at oxygen concentrations of 0 mg L (PBS saturated with 2 MNa2So2), 4 mg L (PBS titration with 2 M) and 8.2mg L (oxygen saturated PBS solution). The solution saturated with dissolved oxygen was equilibrated overnight prior to use. The dissolved oxygen was monitored using a standard Clark electrode (Orion Research Inc., Beverly, MA). The reduction potential of water was assessed in oxygen depleted PBS, to avoid interference from oxygen, at the same time assessing the lower potential limit that could be used for maximizing the efficiency of the sensor. The voltage was then fixed above this reduction potential to assess the dynamic behavior of the sensor upon injection of saturated in oxygen saturated PBS.

C. Transmission

The pill's transmission frequency was measured with respect to changes in temperature. The Type I pill (without crystal) was submerged in RO water at temperatures of 1 C, 11 C, 23 C, and 49 C, whereas the Type II pill (with crystal) was submerged in temperatures of 2 C, 25 C, and 45 C. The change in frequency was measured with the scanning receiver, and the results used to assess the advantage of crystals stabilized units at the cost of a larger physical size of the transmitter.

Dynamic Measurements

Dynamic pH measurements were performed with the pill submerged in a PBS solution at 23 C. The pH was changed from the initial value of 7.3 by the titration of 0.1 M Hand0.1 MNaOH, respectively. Subsequently, the pH was changed from pH 7.3 to pH 5.5 (after 5 min), pH 3.4 (after 8 min) top 9.9 (after 14 min) and back to pH 7.7 (after 21 min). A standard (bench-top) pH electrode monitored the pH of the solution. The solutions were sampled after the pH change, and measured outside the experimental system to prevent electronic noise injection from the pH electrode. The temperature channel was recorded simultaneously.

E. Sensor and Signal Drift

Long term static pH and temperature measurements were performed to assess signal drift and sensor lifetime in physiological electrolyte (0.9% saline) solutions. A temperature of 36.5 C was achieved using a water bath, with the assay solutions continuously stirred and re-circulated using a peristaltic pump. The sensors were transferred from solutions of pH 4 to pH 7, within2 h of commencing the experiment, and from pH 7 to pH 10.5,

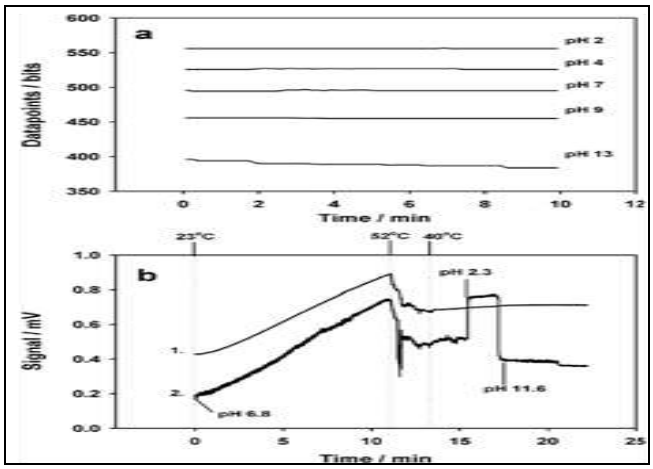

Fig 6: pH sensor: (a) pH recording in the range of pH 2 to 13, represented by digital data points; (b) dynamic recording of temperature (1) and pH (2) using a direct communication link illustrates the temperature sensitivity of the ph. channel

Fig 7: Temperature sensor: (a) temperature recording over a range from 9.1 C to 47.9 C, represented by digital data points; (b) high-resolution plot of a temperature change from 49.8 C to 48.7 C.

The control measurement from the thermocouples is presented as solid points with error bars representing the resolution of the thermometer. The resolution of the temperature channel was noise limited to 0.4 C (16:8 mV C), whereas the temperature channel is insensitive to any pH is chanced use the temperature channel to drift. Thus, bench test measurements conducted on the temperature sensor revealed that the output signal changed by 1.45 mV per mV change in supply voltage ((mV)-1.4Mv expressed in mill volts, corresponding to a drift of -21mVin the pill from a supply voltage change of-14.5Mv.

4. Results

The power consumption of the microelectronic pill with the transmitter, ASIC and the sensors connected was calculated to12.1 mW, corresponding to the measured current consumption of 3.9 mA at 3.1-V supply voltage. The ASIC and sensors consumed 5.3 mW, corresponding to 1.7 mA of current, whereas the free running radio transmitter (Type I) consumed 6.8 mW (-corresponding to 2.2 mA of current) with the crystal stabilized unit (Type II) consuming 2.1 mA. Two SR44bat-teries used provided an operating time of more than 40 h for the micro system.

5. Discussion

Capsules as Actuators

Drug delivery system is an issue of optimization for many interests, immediate release drug will be absorbed in the upper part of the small intestine after stomach, extended-release drug is desired to be absorbed in the lower level of the intestine. Achievement of the second by normal coating tablets is difficult due to the complexity of the GI tract of human being, intubations is an alternative solution, but it is uncomfortable for patients. Alternative solution will be of more interest, and the idea of developing swallowed capsules devices was, over two decades engineers are trying to develop different capsules with the capability to control the time and the location of the drug release. The earlier capsules in this domain were HF, Indelicate, and Telemetric Capsules. They are triggered by a radio frequency (RF) pulse from a generator outside body, the heat generated in the circuit will melt a thread releasing a needle that pierces the container and spells out the drug. State-of-the-art in this domain are the Enteron™ capsule and Chip Rx.

The patient must undergo several gamma scans to identify the location. Telemetric capsule uses a cogwheel means for localization. Enhancement in localization is of more interest and more work can be done in this domain to achieve a practical solution for position determination.

Capsules as Sensors

Monitoring the variation of temperature, pH, motility and other functions are getting easier and comfortable for patients. The need to collect biomedical information within a specific location is of high interest, most of the existing sensor capsules don't provide location determination. Earlier products in this field are the Radio Pill, BRAVO, Heidelberg and Temperature capsules. Almost all of them use internal battery for power consumption. New capsules in this field are A new platform of an electronic pill with bidirectional communication system for miniaturized and low power biomedical applications.

6. Advantages

It is being beneficially used for disease detection & abnormalities in human body. Therefore, it is also called as Magic Pill for Health Care

Adaptable for use in corrosive & quiescent environment

It can be used in industries in evaluation of water quality, Pollution Detection, fermentation process control & inspection of pipelines.

Micro Electronic Pill utilizes a Programmable Standby Mode, So Power consumption is very less.

It has very small size, hence it is very easy for practical usage

High sensitivity, Good reliability & Life times.

Very long life of the cells (40 hours), Less Power, Current & Voltage requirement (12.1 mW, 3.9 mA, 3.1 V) Less transmission length & hence has zero noise interference.

7. Conclusion

We have developed an integrated sensor array system which has been incorporated in a mobile remote analytical microelectronic pill, designed to perform real-time in situ measurements of the GI tract, providing the first in vitro wireless transmitted multichannel records of analytical parameters. Further work will focus on developing photo pattern able gel electrolytes and oxygen and cation selective membranes. The microelectronic pill will be miniaturized for medical and veterinary applications by incorporating the transmitter on silicon and reducing power consumption by improving the data compression algorithm and utilizing a programmable standby power mode. The generic nature of the microelectronic pill makes it adaptable for use in corrosive environments related to environmental and industrial applications, such as the evaluation of water quality, pollution detection, fermentation process control and the inspection of pipelines. The integration of radiation sensors and the application of indirect imaging technologies such as ultrasound and impedance tomography, will improve the detection of tissue abnormalities and radiation treatment associated with cancer and chronic inflammation. In the future, one objective will be to produce a device, analogous to a micro total analysis system (TAS) or lab on a chip sensor which is not only capable of collecting and processing data, but which can transmit it from a remote location. The overall concept will be to produce an array of sensor devices distributed throughout the body or the environment, capable of transmitting high-quality information in real-time.

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