RFID-based wireless health monitoring system design

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Abstract

This research provides a health monitor system with replaceable flexible non-fragile bio-probe on an active RFID (Radio Frequency IDentification) tag, such that the new system can improve the signal-to-noise ratio (S/N) and impedance matching problems. Besides, the bio-probe device can conform to the profile of a bio-body and to improve the electrical contact property. The detailed device fabrication and testing processes are given. Two examples are given to show that it is very useful for remote health monitoring. The first case is used to measure the difference of acupuncture bio-potentials for a man with and without staying up late for all night. The other is to show the difference of acupuncture bio-potentials for a man with influenza before and after taking some tablets of vitamin C.

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1. Introduction

Conventional micro array biological probes are produced on a silicon wafer substrate [1-3]. These probes are fragile and fail to be disposed relying on the profile of a bio-body, and adversely affecting the contact resistance between probes and body. Besides, after a signal detected, additional devices for signal processing are required to improve S/N ratio and impedance matching problems. The bio-sensing probe module and the block diagram of this bio-sensing and health monitoring system are respectively as shown in Figs. 1 and 2, which consists of a replaceable non-fragile bio-probe device, top-gate TFT amplifiers, and a wireless active RFID system[4-8]. As such, the bio-signal can be amplified nearby to improve both S/N ratio and impedance matching. The bio-probes are made of thick SU-8 photo resist, thus they are flexible and non-fragile, such that the bio-probes can be...
disposed to conform to a human acupuncture [9-15] and to improve the electrical contact property. The bio-sensing and health monitoring system is not proposed in the previous literatures [16-25].

The detailed device fabrication processes are given. The probe resistance is 2.7 KΩ, and the monitoring range of the RFID tag is 15m. Two examples are given to show that it is very useful for remote health monitoring. The first case is used to measure the difference of acupuncture bio-potentials for a man with and without staying up late for all night. The other is to show the difference of acupuncture bio-potentials for a man with influenza before and after taking some medicines, such as vitamin C. The paper organization is as follows: the first section is introduction. The second one briefly describes the fabrication steps of TFT amplifier, bio-sensing probe device. The third one is system test and discussions. The last section is conclusion.
2. Device fabrication steps

**Step 1:** Use mask #1 and Photolithography And Etching Processes (PAEP) to make some through holes on flexible substrate #1. Remove Photo Resist (PR) and deposit TiN (0.1 μm) on both sides of substrate as seed to electroplate copper (100μm). Use PAEP to divide the module into two parts to make a pair of MOS TFT amplifiers. Deposit a layer of Si₃N₄ (2μm) on the back of the substrate for humidity insulation and passivation. Use PAEP to make vias on the holes. Deposit a layer of amorphous silicon layer (the active regions of TFTs, 2μm), and use PAEP to make four island regions to make TFT amplifiers, the left-hand two regions are to make two N-MOS TFTs, and the other regions are for CMOS TFT amplifier. Remove PR and anneal amorphous Si to be recrystallized by Nd-YAG laser. The result is as in Fig. 3.

**Step 2:** Deposit layers of SiO₂ (2μm) and amorphous Si (2μm) successively, use PAEP to make the top gate electrodes of TFTs and the wirings connecting to the vias. Use PAEP to etch SiO₂ away at the sources, drains and wirings on the left three NMOS TFTs for phosphorous (N⁺ donor type) ion implantation. Finally remove PR, and the result is as in Fig. 4.

**Step 3:** Use PAEP to etch the regions of SiO₂ away at the source, drain and wirings on the right-hand-side P-MOS TFT for boron (P⁺ acceptor type) ion implantation. Evaporate a layer of Si₃N₄ or SiO₂ (2μm), and use PAEP to make the contact holes for all the electrodes of MOS TFTs and wirings. Finally remove the PR, and the result is in Fig. 5.
Step 4: Evaporate aluminium (2μm) and with mask #8 and PAEP to make the contact metallization for all the electrodes of TFTs and wirings. Finally remove the PR. Deposit SiO_2 or Si_3N_4 (2μm) for insulation and passivation, using PAEP to make the pad connection holes. Then electroless-plating two layers of nickel and gold. The result is in Fig. 6.

Step 5: Making bumps to connect to the outer circuit by solder (silver paste) screen printing with mask #10, and then to cure it by reflowing process. The result is as in Fig. 7. Then the four TFTs are connected as a pair of amplifiers in Fig. 8; they can be used for impedance matching and increasing the signal-to-noise ratio.
Step 6: The replaceable probes are made on substrate #2 as follows: The conducting vias of the microarray bio-sensing probes are formed by using Nd-YAG laser ablation. Form SU-8 thick PR (500 μm) on both sides by using PAEP for deposit TiN with Lift-Off Process (LOP). Deposit copper and TiN on both sides (100 μm) for biocompatibility as shown in Fig. 9.

Step 7: Stripe PR away. The result is in Fig. 10.

Step 8: Forming a layer of Lift-Off resist (LOR, 500 μm) on the back side for deposition of TiN later. Then form another SU-8 thick PR (500 μm) on the back side as the columns of flexible non-fragile probes. The result is shown in Fig. 11.

Step 9: Deposit a layer of TiN (2 μm) on the probe surface for bio-compatibility. Stripe LOR PR away and the microarray probes are formed as shown in Fig. 12. Then connect substrates #1 and #2 with conducting tapes for signal connection. Thus the probe module can be replaced easily after usage by peeling the conducting tapes as shown in Fig. 13. Applying a RFID tag as an interposer, on which the conducting wires to the probes and TFT amplifiers are formed. The holes on the interposer tag are electroplated with copper such that the bio-signals can be connected to the RFID tags as shown in Fig. 14.

Step 10: Screen print silver paste on the contact holes of interposer, after the reflow process one can connect the power, ground, and bio-signals to and from the modules of bioprobe and TFT amplifiers for wireless monitoring as in Fig. 14.
Fig. 8. A pair of amplifiers consist four MOS TFTs.

Fig. 9. Result of step 6.

Fig. 10. Result of step 7.

Fig. 11. Result of step 8.

Fig. 12. Result of step 9.
The circuit diagram to integrate the modules of micro array probes, TFT amplifiers, and active RFID tag is as shown in Fig. 15, in which Q1 is a switch enabled by a pulse signal input voltage ($V_{DD}$) for power saving at point A, Q2 is a current source by connecting gate to drain. The current output from point C is connected to micro array probe module on human acupuncture under test. Meanwhile, the voltage output at point C is connected to the CMOS TFT amplifier previously mentioned for impedance matching as well as raising the signal-to-noise ratio of measurement. Finally, the amplified voltage at point D is converted to digital by an A/D converter in the active RFID chip.

![Diagram of circuit integration](image)

**Fig. 13.** Result to connect substrates #1 and #2 with conducting tapes.

![RFID tag connection diagram](image)

**Fig. 14.** RFID tag is used as an interposer to connect the probes and TFT amplifiers.
3. System test and discussions

This section is for bio-potential tests via RFID reader. As shown in Fig. 16 one set of the micro-probes is affixed over acupuncture H5 (tōnglī) on the back of a wrist, and the other one is connected to the copper cylinder ground held by a hand. The RFID reader is placed at 15m away. The first case is to measure the bio-potentials for a man with and without staying up late for all night as shown in Fig. 17. Noted that the bio-potential with staying up late for all night is much larger than the other one, we have repeated the test of the same person for several times, the results are almost in consistence with each other. Thus the bio-potentials obtained by the proposed device and system can be applied for the diagnosis, remote health care and monitoring of body organs. The second case is to show the difference of acupuncture bio-potentials for a man with influenza before and after taking some tablets of vitamin C, the results of the first five and the second five minutes are as shown in Figs. 18 and 19. Noted the initial value of bio-potential was 0.6V in Fig. 18, it was very high, because the man fell asleep at three o’clock in the morning and catch cold. But the bio-potentials were gradually reduced to smaller values when he took some tablets of vitamin C as shown in Figs. 18 and 19.

4. Conclusion

This research employs the semiconductor and MEMS processes to integrate modules of TFT amplifiers and replaceable micro array probes with an active RFID tag. Thus it becomes possible to dispose the bio-sensing probe in conformity with the profile of the body skin. As such, the contact effect becomes better. The detailed device fabrication and testing processes are given. Two examples are given to show that it is very useful for remote health monitoring.
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Fig. 16. Acupuncture H5 (tōnglì) is on the back of a wrist.

Fig. 17. Bio-potential curves of a man with and without staying up late for all night.
Fig. 18. Bio-potential curves for five minutes after taking vitamin C.

Fig. 19. Bio-potential curves for the next five minutes.

References


