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A Modified Long Lasting Pacemaker Using Piezoelectric Nanowires For Treating Cardiac Diseases

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Abstract: The Pacemakers were the first active implantable devices. Being so commonly known nowadays, their use has been integrated to our daily lives. Only 60 years ago, people with heart diseases would have a very poor quality of life or even died but with the use of pacemakers several heart diseases are not life threatening anymore. In this paper, i would like to present a modification to the formerly used pacemakers that used lithium ion batteries, which were needed to be replaced in every 10 years. Instead we are making use of piezoelectric nanowires for powering up the pacemaker. We have made use of nanowires as they offer low power consumption. In our own work we have used piezoelectric zinc oxide nanowire arrays to demonstrate novel approach of converting nanoscale mechanical energy into electrical energy. The electrical energy obtained from the nano wires is in turn fed into super capacitors which slowly discharges its energy into the pacemaker forming a closed loop circuit. Modern pacemakers are typically about 6 to 8 millimeters thick, and about the same diameter as a 50-cent coin; about half of that space is usually occupied by the battery. The new supercapacitor is only 1 micrometer thick much smaller than the thickness of a human hair meaning that it could improve implantable devices' energy efficiency. It also can maintain its performance for a long time, bend and twist inside the body without any mechanical damage, and store more charge than the energy lithium film batteries of comparable size that are currently used in pacemakers

Keywords—Pacemaker, Zincoxide, nano wires, Piezoelectric, electrical energy, super capacitors.

1. INTRODUCTION

The development on the synthesis technique of the piezoelectric nanomaterials has promoted the miniaturization of the piezoelectric generators.Wang and Song firstly reported the piezooelectric nanogenerators in 2006, which can generate impulsive voltage with several millivolts by bending a ZnO nanowire with the atomic force microscopy tip. This nanogenerator has attracted great interest of researchers due to the great potential in the application of micro/nanoscaled power supply systems. However, the energy conversion efficiency and output power of this early-stage device are too low to be applied. In the last 8 years, researchers have done great efforts on improving the device performance, including the employing of several kinds of piezoelectric materials with higher piezoelectric properties. In this paper, we firstly reviewed the fundamental theory about the piezoelectricity and piezoelectric materials

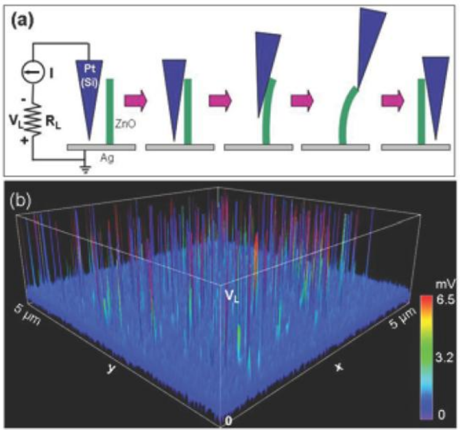

Figure-1(Zinc nanowires)

Figure-1 shows our experimental setup, in which a zigzag silicon electrode coated with platinum covers an array of aligned ZnO NWs. The platinum coating isn't only for enhancing the electrode's conductivity but also for creating a Schottky diode at the interface with ZnO. Then, we placed the electrode above the NW arrays, manipulated it from a controlled distance, and carefully packaged it to separate the electrode from the NWs. we observe conversion of mechanical energy into electric energy by a piezoelectric ZnO wire, shown via two characteristic snapshots and the corresponding topography and output voltage images. The AFM tip pushes the wire toward the right side but doesn't go above and across its width, which the topography image indicates. We didn't detect any output voltage. The AFM tip pushes the wire toward the right side and goes above and across its width, as the peak in the topography image indicates. The output voltage image showed a sharp negative peak. There is a delay in the output voltage peak in reference to the normal force image (the peak in the topography image). "Y" represents the relative position of the scanning tip perpendicular to the wire.

2. METHODOLOGY

A detailed methodology will give a clear view as to how the device functions. The block diagram given below will provide the basic circuitry of this device.

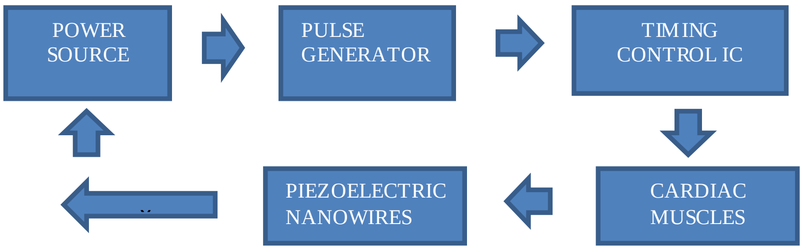

Fig-2.Block Diagram

The pulse generator is powered up by using a power source, the output signals from the pulse generator are then controlled by using timing control IC in our case its 555 timer IC.Then the output pulse is sent into the heart ventricles by using electrodes. In our system the nano piezoelectric wires connected to the cardiac muscles in heart act as a power source feeding back the power generated by conversion of stress into electrical energy which is then fed back to the power source.

Conventional pacemakers work as part of a pacing system that consists of a pulse generator and pacing leads. Pulse generator: a device implanted just below the skin near the collarbone. The pulse generator contains the battery and the electronic circuitry, or brain of the pacemaker, which directs the battery to send electrical pulses to the heart. Leads: thin wires that are inserted through a vein, which connect the generator to the heart. The leads also pick up the patient's own heart rhythm and transmit this information to the generator, which adapts its responses to the patient's needs.

Unlike conventional pacemakers, a leadless pacemaker is placed directly in the heart without the need for a surgical pocket and pacing leads. The device is much smaller than a conventional pacemaker and is comprised of a pulse generator that includes a battery and a steroid-eluting electrode that sends pulses to the heart when it recognizes a problem with the heart's rhythm. Leadless pacemaker technology is made up of computer chips and a small array of super capacitors fabricated from nano materials like ZnO. The array of nano rods are created with transparent top and bottom electrodes.

It is very essential that the timing control IC used in the device is configured as per the needs. This prototype uses a integrated circuit which can work in both astable and monostable mode of operation. In the monostable maode 555 timer outputs a high pulse. A monostable is a single stable state, i-e the off state. Whenever it is triggered by an input pulse, the monostable switches to its temporary state. It remains in that state for a period of time which is determined by an RC network.

Astable mode outputs an oscillating pulse signal. The output switches between high and low states at a tunable frequency and pulse width. Frequency depends on the values of the two resistors (R1 and R2) and capacitor C1.

Figure-3 (555 timer IC)

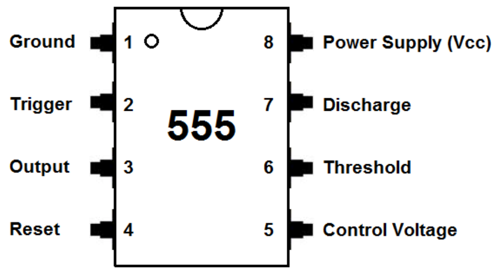

Figure-4 Pin Diagram

INTEGRATED CIRCUIT SPECIFICATIONS:

PIN.NO	NAME	I/O	DESCRIPTION
1	GND	O	Ground reference voltage
2	Trigger	I	Responsible for transition of SR flip flop
3	Output	O	Output driven waveform
4	Reset	I	A negative pulse on reset will disable or resset the timer
5	Control voltage	I	Controls the width of the output pulse by controlling the threshold and trigger values
6	Threshold	I	Compares the voltage applied at the terminal with a reference voltage of 2/3
7	Discharge	I	Connected to open collector of a transistor which

			discharges a capacitor between intervals
8	Vcc Spply	I	Supply voltage

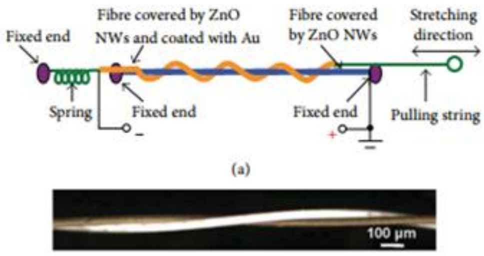

Figure -5 Zincoxide nanowires

The above figure shows how zinc oxide nanowires are used In creating an emf by being rubbed against each other . The Output voltage is obtained from the ends of the string.

3. SIMULATION

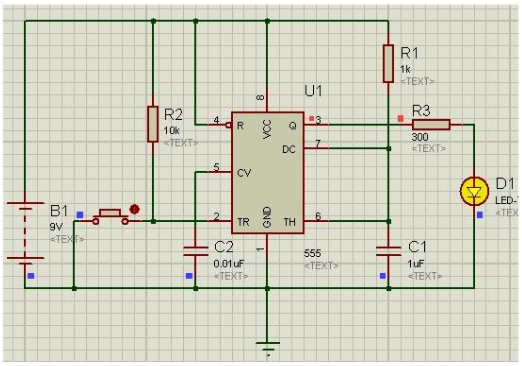

Figure-6 555 timer in monostable mode

The above figure shows simulation of 555 timer IC configured in Monostable mode. When trigger pin is set low, it gives high output and then output goes low.

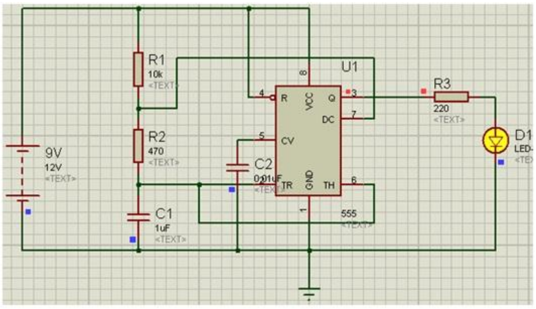

Figure-7 555 timer in astable mode

The above figure shows simulation of 555 timer IC configured in Astable mode. When trigger pin is set low, it gives high and low output pulses.

The Astable and Monostable mode are both used together in development of pacemaker circuit.

4. CALCULATION

A .Calculating piezoelectric potential

The maximum potential at the NW's surface is directly proportional to the NW's lateral displacement and inversely proportional to the NW's length-to-diameter aspect ratio. The maximum potential voltage (V) at the NW's surface at the tensile (T) and compressive (C)

$$V_{\max}^{(T,C)} = \pm\frac{1}{\pi}\frac{1}{\kappa_0+\kappa_\perp}\frac{f_y}{E}[e_{33}-2(1+\nu)e_{15}-2\nu e_{31}]\frac{1}{a} \qquad (1)$$

Piezoelectricity is the linear interaction between the mechanical and electrical properties of the dielectric materials.

the relationship between the electric displacement (Di) and the electric field (Ej) can be interpreted as

$$D_i = \sum_{j=1}^{3}\varepsilon_{ij}E_j,$$

The relationship between stress and strain under small deformations can be interpreted as

$$T_{ij} = \sum_{k,l=1}^{3} c_{ijkl} S_{kl}, \qquad (2)$$

Where $cijkl$ is the elastic stiffness of the material. Equation (2) can also be interpreted reversely as

$$S_{ij} = \sum_{k,l=1}^{3} s_{ijkl} T_{kl}, \qquad (3)$$

In reduced notation, the piezoelectric constitutive equation can be interpreted as

$$\begin{aligned} D_i &= \varepsilon_{ij}^{T} E_j + d_{iJ} T_J, \\ S_I &= d_{Ij} E_j + s_{IJ}^{E} T_J, \end{aligned} \qquad (4)$$

Where the superscripts T and E mean the coefficients are at constant stress and electric field, respectively. The diJ in (4) is the piezoelectric strain/charge constant. Under the one-dimensional simplified hypothesis, the piezoelectric constitutive equation can also be interpreted as follows:

$$\begin{aligned} S &= s^{E} T + dE \\ D &= dT + \varepsilon^{T} E \end{aligned} \qquad (5a)$$

$$\begin{aligned} S &= s^{D} T + gD \\ E &= -gT + \frac{D}{\varepsilon^{T}} \end{aligned} \qquad (5b)$$

$$\begin{aligned} T &= c^{E} S - eE \\ D &= eS + \varepsilon^{S} E \end{aligned} \qquad (5c)$$

$$\begin{aligned} T &= c^{D} S + hD \\ E &= -hS + \frac{D}{\varepsilon^{S}}. \end{aligned} \qquad (5d)$$

Among them, d, e, g, and h are piezoelectric constant and can be linked as

$$
\begin{aligned}
d &= \varepsilon^{T} g = s^{E} e \\
e &= \varepsilon^{S} h = c^{E} d \\
g &= \frac{d}{\varepsilon^{T}} = s^{D} h \qquad (6) \\
h &= \frac{e}{\varepsilon^{S}} = c^{D} g \\
\varepsilon^{T} &= \varepsilon^{S} + de.
\end{aligned}
$$

5. CONCLUSION

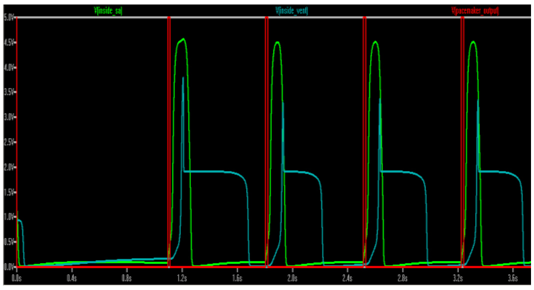

Figure-8 Output

The above graph represents the output obtained from the pace maker circuit using cathode-ray oscilloscope. The red colored waveform shows the heart beat of the patient and the other waveforms are the output obtained from the pulse generator .

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