Medicine Insights

Article

Research on Advanced Imaging System Based on PZT Material and X-ray Tube

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Abstract: Along with the rapid development of social economy and the continuous improvement of people's living standards, medical and health care has taken on an important strategic position. As an important analysis and detection means, biosensing technology plays a key role in the field of healthcare. The piezoelectric biosensor is an innovative biosensor utilizing piezoelectric material for bioanalysis, which has excellent characteristics of good stability, fast detection speed, high accuracy and simple operation, and has important application value in the fields of biomedicine, health monitoring and disease prevention and control. Herein, we summarize the research progress of piezoelectric biosensors at home and abroad in recent years and introduce the working principle of piezoelectric biosensors based on the piezoelectric effect of quartz crystal microbalance as well as commonly used piezoelectric materials, including inorganic piezoelectric materials, organic piezoelectric materials, piezoelectric composites, and bio-piezoelectric materials. Furthermore, the applications of piezoelectric biosensors in human health monitoring and disease prevention and control, such as the monitoring of physiological signs such as heart rate and pulse, the detection of biomarkers and epidemic viruses such as neo-coronary pneumonia, are also introduced. Finally, the current problems faced by piezoelectric biosensors are summarized and their future development is prospected. We will also talk about the basic principle, type, detection technology, application and development trend of X-ray tubes are reviewed. X-ray tube is a kind of electronic device that can produce X-rays, which is widely used in medical, industrial, security and other fields. The basic principle is to obtain the internal structure and composition information of the sample by detecting the intensity and energy distribution after the X-ray passes through the sample by using the penetration and fluorescence effects of the X-ray.

Keywords: PZT; X-Ray; medical imaging; biomedical engineering

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1. Introduction

With the growth of modern science and technology, PZT and X-ray tubes, as two crucial materials and technologies, are playing more and more important roles in their own application fields. PZT, as a typical piezoelectric ceramic material, has excellent piezoelectric and ferroelectric properties and is widely used in sensors, actuators, transducers and so on. While X-ray tubes are the core part of X-ray imaging technology and are widely applied in medical diagnosis, industrial inspection, material analysis, and scientific research and many other fields.

The research on PZT started in the 1950s. Because of its unique piezoelectric effect and ferroelectric properties, it has gradually become a research hotspot in the field of piezoelectric materials. The piezoelectric properties of PZT allow it to convert mechanical energy into electrical energy or electrical energy into mechanical energy. This feature makes it have wide application prospects in sensors and actuators. Besides, the ferroelectric properties of PZT make it have potential application value in memories and capacitors.

The research on X-ray tubes can be traced back to the late 19th century. As X-rays were discovered, X-ray tubes gradually became the core part of X-ray imaging technology. The principle of X-ray tubes is to generate X-rays by bombarding a metal target with high-speed electrons. We can get the internal structure and composition information of the sample by detecting the intensity and energy distribution of the X-rays passing through the sample. X-ray imaging technology has the advantages of being non-destructive, efficient and accurate, and it has wide applications in the medical, industrial and security fields.

In recent years, with the continuous development of technology, significant progress has been made in the research and application of PZT and X-ray tubes. For PZT, researchers have improved the preparation process and optimized the material composition to enhance the piezoelectric and ferroelectric properties of PZT, making it have higher performance and broader application prospects in some application areas. For X-ray tubes, researchers have improved the structure and performance to enable them to generate higher-quality X-rays and improve the resolution and accuracy of imaging.

However, although PZT and X-ray tubes have achieved remarkable results in their respective application fields, there are still some problems and challenges. For example, the piezoelectric and ferroelectric properties of PZT are affected by factors such as temperature and stress, and need further optimization and improvement. X-ray tubes have problems such as radiation safety and equipment cost, and more safe and efficient X-ray imaging technologies need to be researched and developed.

Therefore, this article aims to review the latest research progress and application status of PZT and X-ray tubes, discuss the existing problems and challenges, and the future development trends. Through the research of this article, it can provide references and learnings for researchers and users in related fields, and promote the further development and application of PZT and X-ray tube technologies.

2. PZT

2.1. Introduction of PZT

PZT is a material with the piezoelectric effect. That means an electric field can make it deform, and it can also generate an electric field by deforming. Because of these features, PZT is widely used in sensors, motion controllers, speakers, machine vibration control, and medical diagnostic equipment.

PZT piezoelectric ceramic materials with stable internal structure and excellent mechanical-electrical energy conversion ability are the hot spots of functional materials research nowadays. At present, the preparation technology of PZT piezoelectric fibers is relatively mature, but the optimization of the performance of PZT fibers still needs to be improved, especially for the polarization process of single PZT piezoelectric fibers with a large aspect ratio is not yet sufficiently studied. Therefore, researchers are urgently looking for an efficient polarization method to give full play to the performance of piezoelectric fibers.

The main characteristics of PZT are high sensitivity, a wide frequency response range, high mechanical strength, and good thermal stability. It's easy to process and shape and can be made into all kinds of shapes. Moreover, its piezoelectric effect can work in a wide range of temperatures and pressures, making it very suitable for achieving precise control and measurement.

2.2. Application of PZT

PZT can be used in all kinds of places, from sensors and actuators to acoustic and electronic devices. When controlling robots and power systems, it can be used to suppress vibrations and achieve precise position control. In the medical field, it can be used to make the images clearer and improve the accuracy of diagnoses. It can also be used as a vibration energy collector in generators or as a battery energy storage device in charging systems. In a word, PZT has many uses. Its high sensitivity and precise control features are used in many industrial and medical devices.

2.2.1. Application in Medical Ultrasound Imaging

Medical ultrasound imaging is a non-invasive way of checking the internal organs and structures of the human body using high-frequency sound waves. By sending sound waves to the human body and receiving the echoes, we can generate ultrasonic images. Considering the acoustic features of the human body, the best frequency range for general medical ultrasound imaging is usually from 1.0 MHz to 12.0 MHz.

To make sound waves, we need to use a piezoelectric transducer (PZT). When voltage is applied to the PZT, it physically expands and contracts, converting electrical energy into sound energy. The PZT needs to be stimulated by a high-voltage pulse signal. A signal generator can produce pulse signals with amplitudes up to ±90V and currents up to ±2.0A. At the same time, the PZT is also used to convert the received sound wave echoes into electrical signals, that is, the received signals. By processing and analyzing the received signals, we can build the corresponding ultrasonic images.

To better understand the specific operating principle, let's first study how a single-channel PZT works.

As shown in Figure 1, during the transmission period, the signal generator produces a 5 MHz ±90 V high-voltage pulse signal and applies it to the PZT. Thus, the PZT generates a 5 MHz sound wave that enters the human body, and then the receiver starts to listen for echoes. The speed of the sound wave propagation in the human body is on average 1.54 mm/μs. To create an image of a monitoring object that is 10 mm away from the PZT, the calculation formula for the time it takes for the sound wave to reach the object is: 10 mm / (1.54 mm/μs) = 6.49 μs. Similarly, it takes another 6.49 μs for the sound wave echo to return from the monitored object to the PZT. So, for an imaging object that is 10 mm away from the PZT, the time to receive the signal is 12.98 μs. Therefore, when the imaging object is farther away from the PZT, the duration of the receiving period is longer. Once all the echoes are received, a row of images can be constructed.

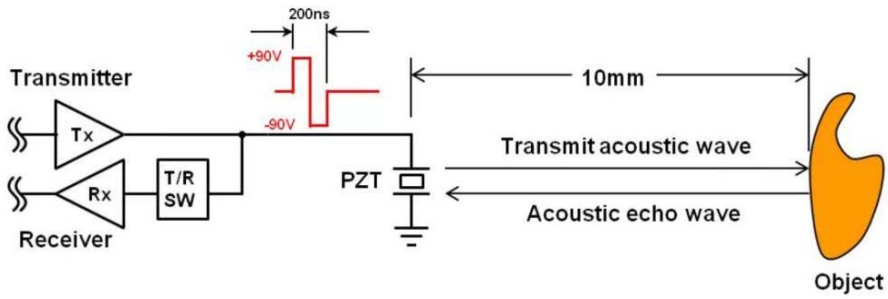

Figure 1. Operating principle of Single-Channel PZT

The receiver is a high-performance, low-noise, low-voltage device. If the high-voltage pulse generated by the transmitter is directly added to its input end, it can easily damage the receiver. In Figure 1, a T/R SW module is added to the front end of Rx. It is a transmit/receive switch used to block the high-voltage transmit pulse but allow the low-voltage receive signal to enter the input of the receiver. The voltage transformed by the PZT is usually relatively low in amplitude, less than ±500 mV.

We just introduced the imaging principle of a single PZT. If we want to create a two-dimensional image, we need an array of PZTs. Ultrasound probes are used to place the PZTs array.

In practical applications, we will see many different types of ultrasound probes, such as abdominal probes, cardiac probes, and pediatric probes, all designed specifically for different application scenarios. The number of PZTs can vary depending on the type of detection, ranging from 128 PZTs to 512 PZTs. In this article, we take the probe with a 192 PZTs array as an example.

Figure 2 shows a typical 192-channel PZTs medical ultrasound system. Theoretically speaking, 192 PZTs need to be equipped with 192 transmitters, receivers, and T/R switch groups. If designed like this, the circuit is very complicated and the cost is very high. Therefore, a high-voltage switch device is introduced. The main function of the high-voltage analog switch is to select and switch, multiplexing the transmitters, receivers, and T/R switch groups to different PZTs. The use of high-voltage analog switches can greatly reduce the cost, power, and volume of the overall solution.

In the example in Figure 2, there are 64 groups of transmitters, receivers, and T/R switches in the circuit, each driving three PZTs. The analog switch group corresponds to 64 groups of transmitters, receivers, and T/R switches, first driving PZT1 to PZT64. 64 transmitters send high-voltage pulses to PZT1 to PZT64, and then the system waits to receive all the echoes from PZT1 to PZT64. In the next cycle, the analog switch re-selects the 64 groups of transmitters, receivers, and T/R switches to drive PZT2 to PZT65. 64 transmitters send high-voltage pulses to PZT2 to PZT65, and the system waits to receive all the echoes from PZT2 to PZT65. Through the analog switch, this series of actions of transmitting, receiving, and re-selecting is repeated, and the increment of one PZT is updated each time. After 192 cycles are completed, an image can be built in about 50 ms.

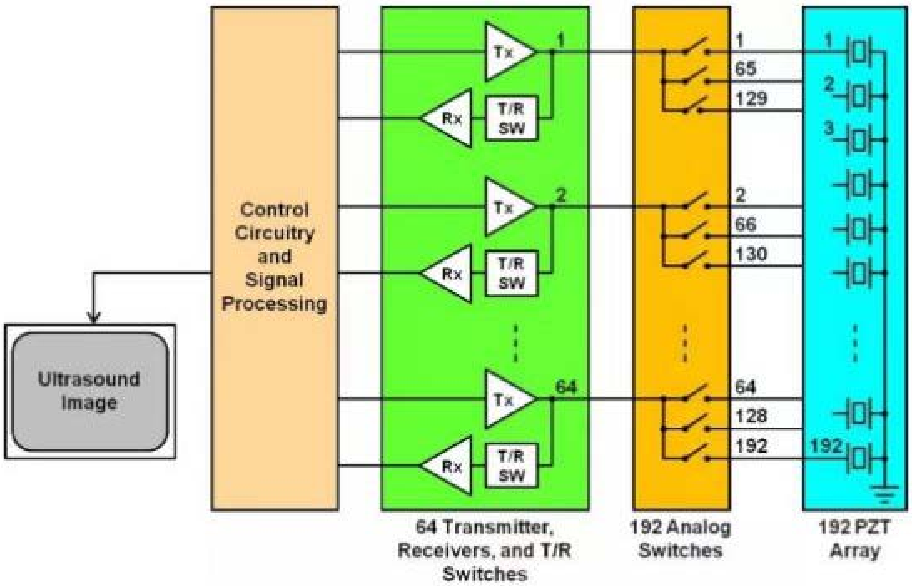

Figure 2. A typical 192-channel PZTs medical ultrasound system

In traditional solutions, high-voltage analog switches are usually placed inside the device. Now, in some solutions, the analog switch is also placed inside the probe. Its main advantage is that the number of coaxial cables can be greatly reduced. For example, for a 192-channel PZT ultrasound probe, by using 3 sets of analog switches, the number of coaxial cables can be reduced by two-thirds. Compared with 192 coaxial cables, PZTs only need 64 coaxial cables, and the logic power supply and I/O interface only need 10 or fewer coaxial cables. Coaxial cables are very expensive, and the reduction in the number of coaxial cables greatly reduces the cost of the ultrasound probe. In addition to the material cost, the labor cost of connecting the coaxial cables is also high.

Another advantage of placing the high-voltage switch inside the probe is that the probe becomes easier to operate and reduces probe fatigue. Probes usually have strict space and heat dissipation limitations. The housing is waterproof, and it must be soaked in alcohol for disinfection after use, which makes it difficult to remove the heat generated inside the probe. The use of the high-voltage switch eliminates the high-voltage DC lines on the coaxial cables and eliminates the safety hazard.

Figure 3 shows the basic difference between the traditional analog switch and the MPS analog switch.

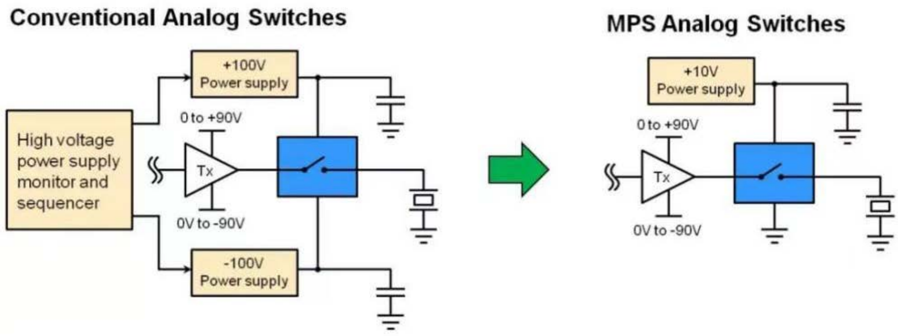

Figure 3. Basic difference between the traditional analog switch and the MPS analog switch

Traditional high-voltage analog switching circuits require two additional high-voltage power supplies of +100V and -100V. The pulse signal through the analog switch must be within the 10V range of the high voltage power supply. For example, for ±100 V high-voltage power supplies, the maximum transmission voltage of the pulse signal is ±90V. These two high-voltage power supply circuits are more complex, and are designed to be used in traditional analog switches in the circuit, and they are not needed elsewhere in the system. Due to the relatively high voltage of the two high-voltage power supplies, the protection circuit must be considered to eliminate the risk of shock in various fault situations, such as insulation damage. For safe operation, consider the sequence of power on and power off. It must also be monitored, and if the voltage level of the high voltage supply is too low, the transmitter pulse signal voltage must be adjusted.

2.3. PZT's Advancement Compared with the Traditional High-Voltage Switches

At present, common medical ultrasound transducers are usually made of piezoelectric ceramics. But traditional piezoelectric ceramic transducers have quite a few flaws. For examples, they have poor shock resistance, are really heavy, don't match the sound impedance of human tissue, and are super big when used at low frequencies.

So, to solve the problem of sound impedance matching, a coupling agent is needed during use to fill the gap. This can reduce energy loss and improve detection sensitivity. But in some situations where coupling agents can't be used, there's nothing we can deal about with. Also, traditional piezoelectric ceramics are rather hard and may cannot have a good contact with human tissue, especially on uneven tissue surfaces or the irregularly shaped organs inside the human body. But ultrasound transducers made of flexible PZT piezoelectric thin film can solve these problems really well.

Because the flexible PZT piezoelectric thin film material has a high dielectric constant, a low sound wave speed, a high coupling coefficient, high longitudinal and transverse piezoelectric coefficients, and good environmental temperature stability, the sensors made from it are small, light, soft, and thin. They will not add any burden to the object being tested. They can stick to uneven surfaces, are resistant to high temperatures, high humidity, corrosion, and sunlight, and have a wide range of application prospects.

The advantages of PZT piezoelectric films in the field of medical ultrasound are as follows:

1) The ultrasonic sensor is small, can be conformal design, miniaturized ultrasonic devices in addition to in vitro applications, more suitable for high precision probe applications in vivo! And reduce the impact of complications.

2) The orientation of the PZT piezoelectric film crystal is controllable and the lattice consistency is good, so the produced ultrasonic device has high sensitivity and clear imaging, and can detect more subtle tissue lesions.
3) PZT piezoelectric film has the characteristics of self-polarization, very small voltage can be driven, unlike the traditional piezoelectric ceramics need high voltage to polarize the electric field; Therefore, PZT piezoelectric films can precisely control the radiation dose through voltage, which is safe and controllable in the medical field! It has great advantages in some medical applications.
4) No coupling agent, matched with human tissue sound, suitable for body surface/body application, can be coupled through air, without affecting the test effect.
5) As an inverse piezoelectric effect application, vibration energy can be accurately controlled to minimize the damage to the tissue! For example, calcification therapy for small blood vessels is a subversive application for thrombus patients.

2.4. PZT's Future Improvement

A team from the State Key Laboratory of Fudan University published a paper entitled "Development of Broadband High-Frequency Piezoelectric Micromachined Ultrasonic" on the website of the scientific journal Transducer Array "research report, by adding PDMSM (polydimethylsiloxane) as the backing material in PMUT (piezoelectric micromechanical ultrasonic transducer), the bandwidth of the device can be doubled without changing the size of the component. The piezoelectric thin film material is the core component of PMUT device, and the piezoelectric thin film material in this research experiment is from Zhuo Mo Technology Co., LTD. The research and development team of Zhuo Mo Technology deposited "electrode material (Ti/Pt)" and "PZT piezoelectric film" on the silicon substrate provided by the company. PZT piezoelectric film will produce deformation and ultrasonic pulse when energized. The experiment is made use of this property. In this experiment, the device was tested using a 10 ns long 30 V pulse, and in air, the resonant frequency of the PMUT was 19.0 MHz. In this experiment, PZT piezoelectric film shows the advantages of good stability, high pressure resistance and sensitive response.

Existing studies have found that PMUT imaging has more advantages than traditional B-ultrasound imaging. Traditional ultrasound involves applying a lubricant to remove air between the instrument and the skin. The probe is large and has only one probe, which requires scanning back and forth. PMUT is a multi-array technology that can eliminate the impact of air directly used, the probe is small and has multiple, only one scan can be completed, faster and shorter time; PMUT can be made into a handheld wireless device, the image is directly transmitted to the mobile phone or other devices, the transmission mode is more convenient and fast; The PMUT device is smaller than the traditional B-ultrasound, uses a small power supply, is convenient to carry, and has higher convenience. There are good prospects for future development. Zhuo Mo Technology can provide materials and related technical support in PMUT.

3. X-Ray Tube

3.1. X-Ray Tube Introduction

X-ray tubes are vacuum diodes that operate at high voltages. It contains two electrodes: a filament for emitting electrons, which acts as a cathode, and a target for receiving electron bombardment, which acts as an anode. Both poles are sealed in a high-vacuum glass or ceramic enclosure.

The X-ray tube has two electrodes: the anode and the cathode. The anode is for receiving the electron bombardment and it's like the target material. The cathode is the filament that shoots out electrons. Both of these electrodes are sealed inside a glass or ceramic casing in a high vacuum. The power supply part of the X-ray tube should at least have a low-voltage power supply to heat up the filament and a high-voltage generator to apply high voltage to the two electrodes. If enough current goes through the tungsten filament, it'll create an electron cloud. And when there's enough voltage (in the kilovolt range) between the anode and the cathode, the electron cloud will be pulled to the anode. At this time, the electrons will hit the tungsten target at high energy and speed. When the high-speed electrons reach the target surface, their movement is suddenly stopped. A small part of their kinetic energy turns into radiation energy and is released as X-rays. This kind of radiation produced in this way is called bremsstrahlung. By changing the size of the current in the filament, you can change the temperature of the filament and the amount of electrons it emits. This then changes the current in the tube and the intensity of the X-rays. By changing the excitation voltage of the X-ray tube or choosing a different target material, you can change the energy of the incoming X-rays or the intensity at different energy levels. Because of the bombardment by high-energy electrons, the X-ray tube gets very hot when it's working. So, the anode target material has to be cooled down forcefully. Even though the energy efficiency of the X-ray tube in making X-rays is really low, up to now, the X-ray tube is still the most practical thing for making X-rays and has been widely used in all kinds of X-ray instruments. The main uses in the medical field now are divided into diagnostic X-ray tubes and therapeutic X-ray tubes.

The requirements for an X-ray tube are that the focus should be small and the intensity should be big. Only like this can a relatively large power density be formed. So, a relatively large power has to be provided to the anode. But the efficiency of the X-ray tube is very low. More than 99% of the power of the electron beam becomes heat loss on the anode, making the focal spot overheat. To avoid overheating of the anode, the way is to cool the anode or the tube in different ways. Lower the temperature at the focal spot or tilt the target surface at an angle to have a larger heat dissipation area. Later, there were rotating anode X-ray tubes. Because the target surface can rotate at high speed (up to 10,000 revolutions per minute), it allows for high power density and a small focus. In today’s world, there's a type of X-ray tube where a control grid is installed between the anode target and the cathode. By applying pulse modulation on the control grid, you can control the output of the X-rays. By changing the width and repetition frequency of the pulses, you can adjust the timing and repetitive exposure.

3.2. X-Ray Tube’s Application

3.2.1. Dental Equipment

In this case, an X-ray film of about 30x40 mm size is placed between the diseased teeth, and only a few teeth can be photographed.

The internal distance between the X-ray objective lens and the X-ray tube focus is quite small, generally about 150-250mm, so the amplification factor is large, which is easy to cause inaccurate focusing. For this reason, the use of 0.8-1.2mm small focus ray tubes, especially 0.8mm focus X-ray tubes account for the vast majority, almost 90%.

If classified by circuit, dental X-ray equipment has X-ray tube filament converter wire coil and high voltage transformer wire wound together, there are also independent filament transformers and high transformers.

The former is used on minicomputers. The small focus D-081 Toshiba company product is called this type. The feature of this machine is that the filament voltage and the voltage of the high-voltage transformer are added at the same time, and its current and voltage cannot be changed separately. Only the burst time can be selected to control the X-ray output. The latter is used in mid-sized machines, or general purpose portable X-ray machines not only in dental. The circuit is designed so that it can individually change the voltage and current, which can obtain better contrast and film density X-ray illumination drop. Currently, the former circuit accounts for the vast majority because it is low cost, small size and light.

3.2.2. CT Equipment

The domestication of high-end medical equipment has been made a strategic direction for national scientific research and high-tech industries. Medical imaging diagnosis and treatment equipment based on radiation is an important supported direction. Among them, X-ray CT is an effective way for clinical diagnosis. It can find out the structure and shape changes of the human body. With the improvement of medical standards, the market demand for X-ray tubes, one of the core parts of CT, has gone up fast. The tubes are consumables. They last for a few months to a year. There's a constantly growing need for them. Based on the data of the number of CT machines from 2006 to 2015 (19,592 in 2015), annual sales (more than 2,300), and the growth rate (10%), it's estimated that by 2020, the number of CT machines in China will reach about 30,000. The market capacity for X-ray tubes is way more than 10 billion yuan a year. Right now, the mid-range CT X-ray tubes with a heat capacity of 2 to 3.5 MHU cost around 200,000 to 300,000 yuan each. If we guess the price of domestic tubes at 200,000 yuan each, the market capacity is about 2 billion yuan a year. But if we want to reach the level of medical equipment in Japan in 2006, the market capacity for 3 MHu heat capacity CT X-ray tubes is about 12.8 billion yuan a year.

Thanks to the high technical threshold, large investment in CT equipment, long research and development and production cycle, relatively strict technical requirements, high requirements for the comprehensive ability of production enterprises, the market is mainly concentrated in a few enterprises, the concentration is more than 90%. Among them, the high-end CT market is mainly occupied by Siemens, General Medical, Philips and Toshiba. Low-end CT market also includes domestic Neusoft, United Imagine and other enterprises. CT machine manufacturers mostly adopt the global procurement model. GE, Siemens, Philips, Toshiba, can produce their own bulb. In addition to these four, Varian and Dunlee are professional tube manufacturers, and provide the first assembly of the tube or certified replacement tube for the complete plant. At present, CT bulb has not been able to achieve domestic production, and it is completely monopolized by foreign companies such as PHILIPS, VARIAN, GE and SEIMENS. Therefore, the independent research and development of domestic CT bulb has a good and sustainable market prospect and important social impact. In the past and at present, the main enterprises and research units in the domestic research and development of CT bulb, but the use of reverse engineering is without exception. In the face of the complex physical, mechanical, electrical, and material processes of highly integrated tubular, simple reverse engineering of the shortcut encountered great obstacles.

An independent R&D platform and process line have been established, achieving independent innovation in the R&D path and techniques. This primarily encompasses:

1) Innovative design of multi-angle cross-disciplinary R&D paths. The team persists in the intersection of technical research and market orientation, as well as the intersection of scientific and technical issues. Based on market demands, it has systematically identified eight major categories of key technical issues in the R&D of CT tubes and conducted in-depth research and analysis.
2) R&D thought of multi-physical field coupling technology. CT tubes involve the coupling of multiple physical fields such as cathode electron emission, beam optics, beam-target physics, rotor dynamics, heat transfer, accelerator physics, high-voltage physics, thermodynamics, and electro-vacuum physics, and simultaneously involve various electro-vacuum processing techniques. The team utilizes computer numerical simulation technology to perform decoupling and coupling analyses of multi-physical field problems, achieving device optimization design and process improvement, and significantly reducing dependence on experience and time costs.
3) Innovative support for fundamental physical research. The root of the key technology is usually basic physics, materials and other issues, the team used 5μm

precision cathode test platform, vacuum bearing rotating anode target test platform, high dielectric strength ceramic insulation test platform, secondary electronic measurement and analysis system to carry out in-depth research on key physical issues, providing supporting conditions for technological breakthroughs. The domestication and independent R&D of CT tubes will break the foreign monopoly in this market. It'll save the country's foreign exchange and lower the clinical medical costs at home. As the Belt and Road Initiative keeps going forward, this series of CT tubes with full independent intellectual property rights will be competitive enough to enter the foreign markets as a Chinese brand and make foreign exchange earnings. The ability to do basic physics research on electromagnetic vacuum that was built up during the market-oriented R&D of CT tubes can be used in the R&D of military products in China. It can give guidance to improve the reliability of military electromagnetic vacuum devices and lower the costs.

3.3. X-Ray's Advancements (Medium Frequency X-Ray Tube with the Traditional One)

The traditional X-ray tube, whether fixed anode or rotating anode X-ray tube, is used in the power frequency X-ray machine, the working state of this kind of ray tube is in the cathode temperature limit state, and depends on the open loop control of the power frequency X-ray machine kV and mA, so as to make kV compensation, space charge effect compensation. In the medium frequency X-ray machine, the adjustment of kV and mA is fully electronic closed-loop control, even during the X-ray exposure process. Therefore, it is necessary to change the design idea of the traditional X-ray tube and make its working state to the space charge limitation state, otherwise it will cause the medium frequency X-ray machine to not work properly.

One of the advantages of the medium frequency X-ray machine, the overall structure is compact, lighter weight, especially in the manufacture of the combined ray tube head, the miniaturization of the beam tube is more prominent. The traditional ray tube with the same rated power has a larger outline size.

However, the rotating anode X-ray tube still have lots of advantages, for instance: The rotating anode design allows the X-ray tube to withstand high-power electron beam bombardment, thereby producing high-energy X-rays and shortening the X-ray photography exposure time, thereby improving imaging efficiency. And the way the X-ray tube is designed makes it possible for the X-rays to focus in a small area. This gives a high-resolution imaging result and can show the details of the object being checked clearly. Last but not the least, The selection and design of the anode material makes the X-ray tube have a long service life and can work continuously and stably and the rotating anode design also allows the X-ray tube to be cooled quickly for continuous imaging, improving work efficiency make it very suitable for hospitals' daily used. On no account can we ignore the value of it.

3.4. X-Ray Tube's Future Improvement

The shape and size of the focus of the X-ray tube are affected by the shape of the filament and the focusing structure. In order to ensure the stable shape of the filament, it is necessary to flash before use, and the flash should be sufficient, but the temperature should not be too high to prevent the ductility of the filament from being affected. After the maximum working tube voltage is determined, the focus size is affected by the focusing groove width and the filament assembly height, and the focusing capacity generated by these sizes is different, but interrelated. Combining the simulation results with the focus measurement results, it is helpful to improve the focus structure of the X-ray tube and realize the focus optimization design. The research of electron beam emission system of medical microfocus X-ray tube will promote the rapid development of medical X-ray tube industry. The application of micro-focus X-ray tubes in fluoroscopy, CT and other medical means allows people to detect, diagnose and treat diseases early, and does a good job in disease prevention, which is of great significance for improving the health level of the whole people and promoting sustainable economic and social development.

4. Conclusion

From what has been discuss above, we may safely draw the conclusion that, both PZT and X-ray tube play an key role in today's medical field and medical imagine research, with the continuous progress of medicine science, these two biomedical devices will certainly become more perfect, and some of their current shortcomings will be solved in the future.

As two important functional materials and technologies, PZT and X-ray tubes play an irreplaceable role in their respective application fields. PZT shows great application potential in the field of ultrasonic imaging because of its superior piezoelectric and pyrolytic properties. As the core component of X-ray imaging technology, X-ray tubes play a key role in medical diagnosis, industrial detection and scientific research, such as the examination of dental diseases and the use of CT. In the future, with the continuous development of materials science, engineering technology and information technology, PZT and X-ray tube technology will continue to play a more important role in their respective fields and make greater contributions to the development of human society.

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