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The development and application of CMOS image sensor

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Abstract. This paper focuses on the development of Complementary metal-oxide semiconductor (CMOS) image sensor and its applications in aerospace, medical and automotive fields. Firstly, the representative events in history and the contributions of some companies to CMOS image sensor are described. Subsequently, some characteristics of CMOS image sensor are analyzed in the image field involved. In order to evaluate the performance of CMOS image sensor, single even effect and electronic endoscope structures are analyzed and active and passive range finder experiments are carried out. The results show that the imaging based on CMOS sensor can fully meet the requirements of imaging applications in many fields.

Keywords: complementary metal-oxide semiconductor (CMOS); image sensor; aerospace field; medical field; automotive field.

1. Introduction

Complementary metal-oxide semiconductor technologies are becoming increasingly important in the developing information society, with higher integration and wider application in many aspects of daily life. The most extensive application of CMOS technology is image sensor, which can reduce power consumption and improve reading speed by integrating with other digital circuits of imaging system. This paper introduces the general development history of CMOS image sensors and the contribution of some companies to the development of CMOS image sensors, and also introduces some applications of CMOS image sensors in aerospace, medical and automotive fields. It explains why CMOS image sensors are active in these fields, including its characteristics, comparison with other image sensors, and prospects for its continued use as a major technology in the future.

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2. Development

2.1. History

After Bell Labs invented the charge-coupled device (CCD) in the 1960s, the image sensor realized the digital imaging of converting optical information into electrical information. Charge-coupled device has been active in the image sensor market since then, and still have a certain market value. However, CMOS image sensor occupies the vast majority of the image sensor market with its advantages of low power consumption, strong integration, fast data processing and high reliability. CMOS as the core technology of sensors was first proposed by Fairchild Semiconductor Company in 1963, which published the first paper on CMOS process technology. In 1968, Radio Corporation of America developed the world's first CMOS integrated circuit. Since then until the early 1990s, CMOS image sensor has been difficult to be applied in practice based on passive pixel structure and due to its large noise and image tailing. During this period, the charge-coupled device has made great achievements in imaging field. In 1995, Kodak company realized CCD technology on CMOS, which marks the beginning of commercial use of CMOS image sensor. At the beginning of the 20th century, the development speed of CMOS has steadily increased. Due to its low cost and high performance, CMOS is playing a more and more important role in the image sensor market. In 2015, Sony officially announced to stop large-scale CCD production. This means CMOS image sensor further replaced CCD. In 2019, Because of the progress of CMOS technology, such as advanced lithography technology and shallow trench isolation, CMOS image sensor accounted for 83.2% in the global image sensor market. This means that CMOS image sensor has basically replaced CCD applications. Until now, CMOS image sensor still plays an important role in different fields. In this article, applications of CMOS image sensor in aerospace, medicine and automobile fields will be involved. CMOS image sensors have improved continuously in the historical development, greatly improving the entire imaging market. With its low manufacturing cost and good performance, it will continue to play an important role in many fields.

2.2. Important company

2.2.1. SONY. SONY has been one of the initial companies that set up the development of CMOS image sensor, initiating the back side illumination (BSI) technology. SONY commercialized its first CMOS image sensor, IMX001, in 2000. In 2007, CMOS image sensors with the original columnar parallel analog-to-digital conversion (ADC) circuit were commercialized; In 2009, BSI CMOS image sensors with sensitivity twice that of traditional products were commercialized. In 2012, with the stacked structure of photosensitive pixel unit and signal processing unit, the commercialization of stacked CMOS image sensor with high picture quality, multi-function and miniaturization was realized. In 2015, SONY became the first company worldwide to apply Copper-copper (Cu-Cu) connectivity to CMOS image sensors, enabling miniaturization, high performance and increased production efficiency. SONY has consistently led the CMOS image sensor industry through continuous technological innovation. Looking back on history, the technological innovation that drove the major breakthrough of CMOS image sensors mainly came from the development and innovation of back shot structure and three-dimensional stacked structure.

The BSI technology, earlier proposed by SONY, was significantly crucial throughout the development and the application in the history of development. To elaborate, the back-illuminated sensor places the wiring layer below the photodiode to improve the light sensitivity. This arrangement removes any electrical wiring or electrical obstacles that might block part of the incoming light. Which the backlight structure can avoid the influence of metal wiring and transistors, so as to increase the light intake of the photosensitive pixel, and also can suppress the problem of sensitivity decline caused by the change of light incidence angle. It can take smooth, high-resolution images even in dark places such as night scenes, which create the foundation for SONY imaging sensor technology to step out

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further. Figure 1 shows the structure of front-illuminated CMOS image sensor (FI CIS) and back-illuminated CMOS image sensor (BI CIS).

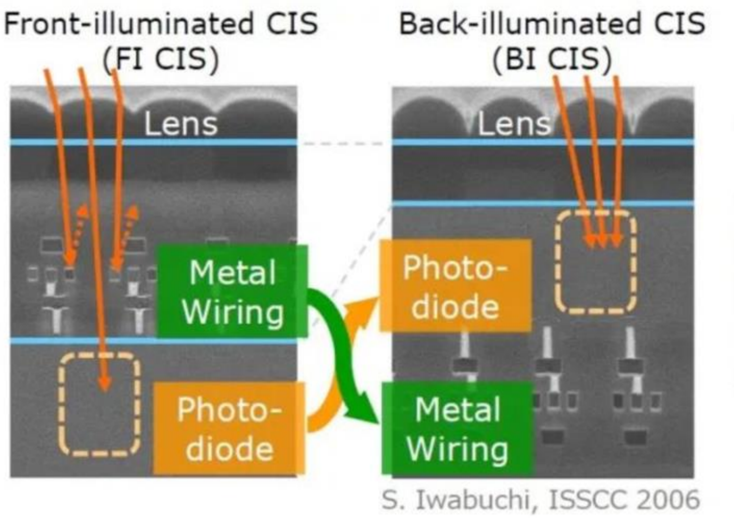
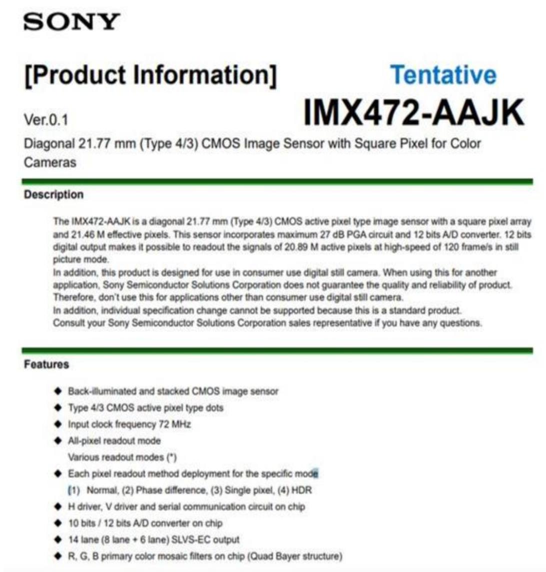


Figure 1. Structure of FI CIS and BI CIS.

A specific application in the use of the BSI technology in SONY's CMOS image sensor, IMX472-AAJK, which is the first BSI CMOS image sensor product. It uses stack technology, overlays dynamic random access memory, and uses the square pixel architecture commonly found on cameras. It supports high-dynamic range output, although the ADC is still 10/12bit. The single pixel size of the sensor is 3.30m*3.30m, the total pixel is 22.93MP, the effective pixel is 21.46MP, and the active pixel is 20.89MP. Figure 2 shows the product information of IMX472-AAJK.


SONY

[Product Information] Tentative

Ver.0.1 IMX472-AAJK

Diagonal 21.77 mm (Type 4/3) CMOS Image Sensor with Square Pixel for Color Cameras

Description

The IMX472-AAJK is a diagonal 21.77 mm (Type 4/3) CMOS active pixel type image sensor with a square pixel array and 21.46 M effective pixels. This sensor incorporates maximum 27 dB PGA circuit and 12 bits A/D converter. 12 bits digital output makes it possible to readout the signals of 20.89 M active pixels at high-speed of 120 frame/s in still picture mode.
In addition, this product is designed for use in consumer use digital still camera. When using this for another application, Sony Semiconductor Solutions Corporation does not guarantee the quality and reliability of product. Therefore, don't use this for applications other than consumer use digital still camera.
In addition, individual specification change cannot be supported because this is a standard product.
Consult your Sony Semiconductor Solutions Corporation sales representative if you have any questions.

Features

- Back-illuminated and stacked CMOS image sensor
- Type 4/3 CMOS active pixel type dots
- Input clock frequency 72 MHz
- All-pixel readout mode
  Various readout modes (*)
- Each pixel readout method deployment for the specific mode
  (1) Normal, (2) Phase difference, (3) Single pixel, (4) HDR
- H driver, V driver and serial communication circuit on chip
- 10 bits / 12 bits A/D converter on chip
- 14 lane (8 lane + 6 lane) SLVS-EC output
- R, G, B primary color mosaic filters on chip (Quad Bayer structure)

Figure 2. IMX472-AAJK

2.2.2. Smart sense. Regarding the development of the Imaging sensor technology, through researches we found out that the innovation Smart Sense did should be remarkable. Firstly, The Global shutter based on stacked BSI technology makes the image sensor have excellent sensitivity and signal-to-noise ratio. At the same time, the voltage domain storage technology is used to effectively improve the shutter efficiency, reduce light leakage, and ensure high quality imaging output in low illumination environment. Secondly, using advanced technology and combined with improved performance and

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inflection point deviation photo response non-uniformity calibration function, to ensure that the image sensor in the application of complex scenarios or movement and light for the accuracy of image capture, greatly improves the motion artifact and the problem of fixed pattern noise is more suitable for image recognition artificial intelligence applications. Finally, have the highest quantum efficiency performance data among existing products in the same category. According to quantum efficiency measurement results, based on stack style.

2.3. How FSI (Front side illumination) and BSI (Back side illumination) influence the imaging sensor technology

2.3.1. In specific situation. Law enforcement agencies in metropolitan areas are increasingly relying on BSI CMOS image sensor technology to record and identify persons at high crime scenes, often in low-light conditions. Artificial intelligence and deep learning behavioral systems with real-time facial biometric data could one day help law enforcement agencies stop crimes before they happen.

2.3.2. In commerce. This breakthrough in the backlight structure has made CMOS image sensors popular in many professional fields and accelerated their replacement of CCD image sensors. In addition, the back-image structure further promotes the development of stacked CMOS image sensors. The stacked CMOS image sensor uses the substrate with logic circuit to replace the supporting substrate required by the backlit CMOS image sensor, so as to meet the miniaturization and multi-function requirements of smart phones.

3. Application

CMOS has three functions: information storage, circuit integration and digital imaging. The first two functions are limited to a small application. In other words, the largest applications of CMOS, and also the most potential, are in the field of digital imaging. This part mainly describes the application of CMOS image sensor in three fields.

3.1. Application of CMOS image sensor in aerospace field

3.1.1. The characteristics of the aerospace field. First, we need to make a distinction between the aviation field and the space field. Aerospace is a general term for the atmosphere and cosmic space, while aviation and space and different in details.

In the aviation field, the nature of different atmospheric components in the environment where the electronic equipment is located will have different degrees of damage to the avionics equipment, such as dust in the desert area, mold in the humid area, these phenomena will cause corrosion and damage to the avionics equipment and cause failure. In addition, in terms of atmospheric pressure, the air pressure in the general working space of avionics equipment is reduced to 1/40 of the ground level, and the air density is reduced to 1/30 of the ground level. These factors lead to thin air, which will affect the normal heat dissipation of avionics equipment and pose a great challenge to the performance of avionics equipment. Lastly, if you work in a place with high humidity for a long time, atmospheric humidity will reduce the electrical strength of the air medium, which can easily cause insulation breakdown, corona and arc discharge, making avionics unable to operate properly in these environments.

In the cosmic space field, the first consideration is the "single event effect" : the radiation effect of a single energetic particle passing through the sensitive region of a microelectronic device that causes an abnormal change in the device's state. It will affect the normal operation of aerospace electronics in cosmic space. Secondly, because the space equipment is in a complex and changeable environment, the use of energy on the equipment needs to ensure high efficiency to ensure the long-term stable and safe operation of the overall equipment. Finally, space equipment is generally required to be small and sophisticated, which also depends on its special working environment. The devices on board aim to use as many functions as possible in as little space as possible.

3.1.2. CMOS applicability in aerospace field. CMOS image sensors have many characteristics that other semiconductor devices do not have in aerospace field. The most typical and applicable four characteristics: low cost, radio-resistance, miniaturization and integration, low energy consumption. This section will focus on the applicability of these four main characteristics to the aerospace field as follows.

Firstly, generally speaking, most kinds of semiconductor integrated chips need to be equipped with special production lines to manufacture their components, but CMOS devices can be manufactured in standard production lines, and these manufacturing equipment can be used to produce about 90% of the current semiconductor chips, which leads to the low production cost of CMOS.

Next, CMOS process technology also makes it possible to design of very large scale integrated circuit, thus the sensor array, the drive and control circuit, signal processing circuit, digital interface circuit, the a/d converter and etc., fully integrated together, realize the single chip imaging system, avoid the use of external support chips and other equipment. This makes the features of CMOS image sensor integration and miniaturization more prominent.

Thirdly, our CMOS semiconductor devices themselves can have the characteristics of radiation resistance through the process of processing and design. "Single event effect" is one of the factors that must be considered in the field of aerospace electronic equipment application. Many types of semiconductor devices will be inevitably affected by solar rays, protons, heavy ions and electron plasma in the earth's radiation belt, so that they cannot work normally. According to the data statistics, the "single event effect" accounted for 45% of the total spacecraft failures [1]. At present, the installation and design of avionics equipment generally have different degrees of requirements on its radiation resistance. Figure 3 shows the signal event effect.

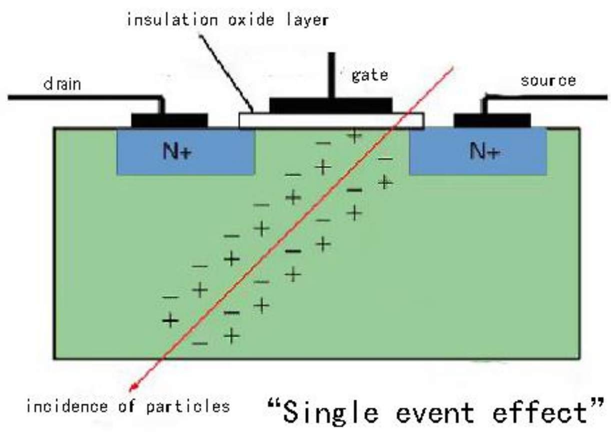

Figure 3. Signal event effect.

Lastly, CMOS devices can achieve low energy consumption performance on the whole device because of its physical structure and human adjustment in process design. And with the continuous progress of process design, CMOS devices have achieved a very ideal dynamic and static power consumption. In general, compared with other semiconductor devices, CMOS image sensors do not require high energy and can achieve many functions, which is very applicable in aerospace field [2].

3.1.3. Comparison of CMOS and CCD image sensing function in aerospace field. In this part, we will compare the characteristics of CMOS and CCD, describe their respective advantages and

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disadvantages, and draw the conclusion that why CMOS devices are more suitable for the aerospace field than CCD devices.

First of all, CCD device due to its own physical structure, its device noise is relatively low, and the image quality is slightly better than CMOS device, and there will be basically no residual image. But these advantages of CCD are not in urgent need in the aerospace field, so relatively speaking, the application of CCD image sensor is more suitable for the field of daily consumer electronic equipment, such as the professional camera with high imaging requirements.

In general, comparing these two devices, in terms of energy demand: CMOS only needs a single power supply and its static energy consumption is very low, the total power consumption is less than one tenth of the CCD; From the perspective of cost: because the components of CCD generally need special production line to manufacture, the cost of CCD is generally three times higher than that of CMOS; From the point of view of function and development: CCD has only a little advantage in image sensing function, which is only suitable for daily consumer electronics. But CMOS devices due to the improvement of integrated circuit design technology and process level combined with its own high integration characteristics, so that CMOS image sensors than CCD image sensors has a broader development prospect [3].

With the continuous development of the performance of CMOS devices in various aspects, its application in practical occasions, especially in the aerospace field, it has replaced CCD image sensor which is widely used in the past.

3.1.4. Development and prospects of CMOS image sensors in aerospace field. With the continuous improvement of integrated circuit manufacturing and design technology, the process limit of integrated circuits has reached 3-5nm, which means that the performance of CMOS devices compared to the previous will get a breakthrough development. Even as early as 2009, science-grade CMOS (sCMOS) has improved the dynamic range of devices by adjusting the semiconductor doping ratio and other technologies and achieved large target surface by two-dimensional seamless stitching technology, overcoming some disadvantages of CMOS. Low noise, high frame rate, high dynamic range, high resolution, large target surface CMOS can make up for its own characteristics of small dynamic range and high device noise, in the performance of the omnidirectional beyond the CCD image sensor [4].

In the current field of aerospace electronics applications, the combination of CMOS devices and Micro-Electro-Mechanical System (MEMS) has basically realized the various functions that aerospace aircraft want to achieve. With the continuous development of science and technology, the combined application of CMOS and MEMS has always been a hot spot in the research of cutting-edge science and technology. With the involvement of more interdisciplinary subjects, the application of CMOS devices in the field of aerospace will have a broader development prospect.

3.2. Application of CMOS image sensor in medical field

3.2.1. The characteristics of the medical field. Due to the limitations of doctors' vision and X-ray scans, a series of medical imaging devices have been developed to observe the tissue morphology and lesions of the internal organs of the human body [5]. These devices need to enter the human body for image capture, which puts forward the following characteristic requirements for these medical imaging devices.

The first is size and safety. Considering the diameter of the internal cavity of the human body, the part of these medical devices entering the human body should be as small as possible, so as to facilitate entering the human body and achieve the image capturing function, while avoiding further damage to human organs and alleviating discomfort during the disease observation process.

The second is flexibility. Given that these medical imaging devices always capture images inside organs, the devices should be able to rotate 360 degrees to find the location of lesions for accurate image capture and disease diagnosis.

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Lastly is device protection. Due to the secretion of digestive juices from human internal organs such as the stomach and small intestine, the devices will be in corrosive environments. To prevent damage when passing through the digestive tract, the surface of the devices needs to be coated to avoid affecting the normal function of the devices.

3.2.2. The structure and principle of electronic endoscopy based on CMOS imaging sensor. Electronic endoscope is a typical application of CMOS image sensor in the medical field. It is widely used to observe the tissue morphology and lesions of human internal organs [6], which can assist and improve the accuracy of doctor's disease diagnosis. Below, we will take the CMOS electronic endoscope as an example to analyze the application of CMOS image sensor in the medical field and explain its internal structure and working principle. Figure 4 shows the structure of the CMOS electronic endoscope.

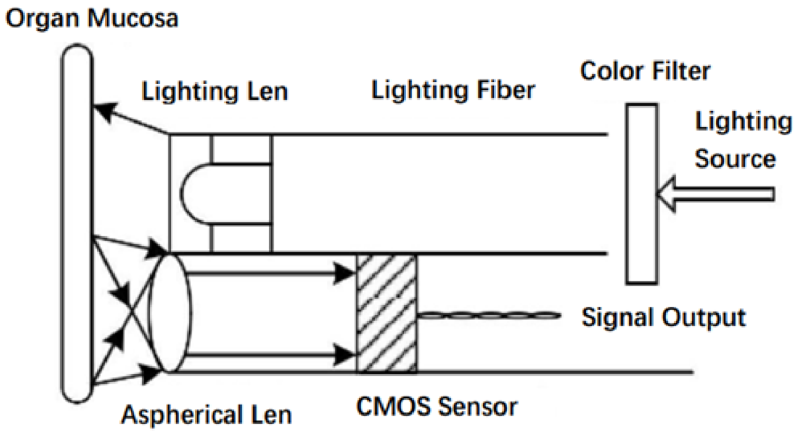

Figure 4. CMOS electronic endoscope.

Since the electronic endoscope needs to enter the human body to check the tissue morphology and lesions of the internal organs, and the inside of the organs is dark and no light, so the endoscope needs to provide its own lighting components. As shown in the figure above, the lighting source passes through the color filter and becomes monochromatic light, and the monochromatic light reaches the front of the electronic endoscope through the optical fiber, and then shines on the mucous membrane of the subject's organs through the illumination lens [5]. The inner wall of the organ reflects the light emitted by the light-emitting device, which is captured by the electronic imaging element CMOS image sensor through the lens. The CMOS image sensor converts the light signal into an electrical signal, and after simple signal processing, the signal is transmitted to the imager through the signal line for further processing, and finally the processed image is presented on the screen of the monitor for the doctors to observe and diagnose. Different endoscopes may have slight variations in structure, but the basic working principle is the same.

3.2.3. CMOS applicability in medical field. CMOS image sensors have the advantages of high integration, low power consumption, and low cost [5], which provide a basis for the applicability of CMOS medical devices based on CMOS image sensors in miniaturization, anti-corrosion and low cost. This section will state the applicability of CMOS in the medical field from these three aspects.

The first one is miniaturization. CMOS image sensor has the characteristic of single-chip high integration, so the CMOS single-chip imaging devices produced has the characteristics of low power consumption and light weight, which is convenient for making ultra-miniature imaging products, and the size can be made like a button [7]. The high integration of CMOS image sensors has enabled the emergence of medical imaging devices such as pill cameras. Due to the small size of these CMOS

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devices, they can easily enter the human body without causing any damage, therefore they are widely applied in the medical field to examine the morphology and lesions of internal organs.

The second one is anti-corrosion. Due to the small size of the CMOS image sensor, there is enough space for the anti-corrosion protection layer. For example, electronic endoscopes are usually covered with a polyurethane plastic tube, which has a sealing and anti-corrosion effect to prevent the entry and corrosion of water and gastric juices [8]. Besides, in 2001, Israel's Given Imaging Technology Company and American Photobit Company jointly developed a cylindrical capsule CMOS camera with a length of 30 mm and a width of 11 mm. In order to prevent damage when passing through the digestive tract, its surface is coated with an anti-corrosion protective coating.[9] All in all, because the size of the CMOS image sensor is small enough, even if an anti-corrosion layer is added, its size is still small enough to easily enter the human body for disease inspection. The small size with anti-corrosion function enables CMOS medical devices to operate stably inside the human body, thus having a wide range of applicability.

The last one is low cost. The low cost of CMOS image sensors brings two benefits to the applicability of CMOS medical devices. On the one hand, low-cost means patients are more likely to afford single-use medical devices since the high cost can easily lead to repeated use of the devices, which increases the risk of cross-infection. On the other hand, low cost will help popularize medical imaging equipment as the cost factor have become the main reason limit the spread of medical devices [5].

3.2.4. The development and prospect of CMOS in medical field. CMOS image sensors have a late start compared to CDD image sensors, and although their performance cannot be compared to CCD image sensors at first, since the late 1990s, CMOS sensors have become a real competitor to CCDs in the medical field due to their low power consumption, low voltage operation, high-speed imaging, low cost, integration capability and other important advantages [10]. At past, due to the poor sensitivity and low signal-to-noise ratio of CMOS image sensors, it was inferior to CCDs in image quality. But the latest CMOS technology improves resolution, color and brightness, and can output better images [11], which has greatly enhanced the competitiveness of CMOS image sensors in the medical field.

Over the past few decades, a series of medical video products based on CMOS image sensors have been developed. Capsule cameras and electronic endoscopes as described in the previous two sections. Among them, the capsule camera has made development and progress mainly in terms of size, and therefore the inspection coverage of the internal organs of the human body is getting higher and higher. While the development of electronic endoscopes mainly focuses on multi-functional aspects. For example, the new medical electronic endoscope developed by East China University of Science and Technology can be operated by remote sensing or touch menu, realizing the functions of endoscope camera 360-degree rotation, photography, audio recording, video recording, zoom in, zoom out, playback, long-distance observation and other functions through electric control [8].

Moreover, since the quality of CMOS devices can be improved with the advancement of semiconductor technology. With the continuous development of CMOS technology and the further improvement of integration, the CMOS image sensor will become smaller and smaller in the future, with higher and higher imaging quality. Advances in device size and resolution could bring broader prospects for CMOS image sensors in the medical field.

3.3. Application of CMOS image sensor in automotive field

3.3.1. Active range finder. Range measurement is the biggest function of automobile image sensor, and image resolution greatly affects the accuracy of automobile range measurement. When the car is moving, it will produce residual shadows, and it is also easy to appear overexposure under strong light in the daytime. CMOS image sensor has greatly improved the resolution of range finder by introducing sub-pixel processing technology. When the vehicle moves at a certain speed to measure its distance from the obstacle, not all the image information around the vehicle can be used. On the

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contrary, only a few specific information is valid. The key image information can be captured well by using optical triangulation. In triangulation, the sensor determines the distance between the target and the vehicle by processing the reflected light and scattered light after the laser diode irradiates the target. Figure 5 shows an experimental model of the triangulation measurement.

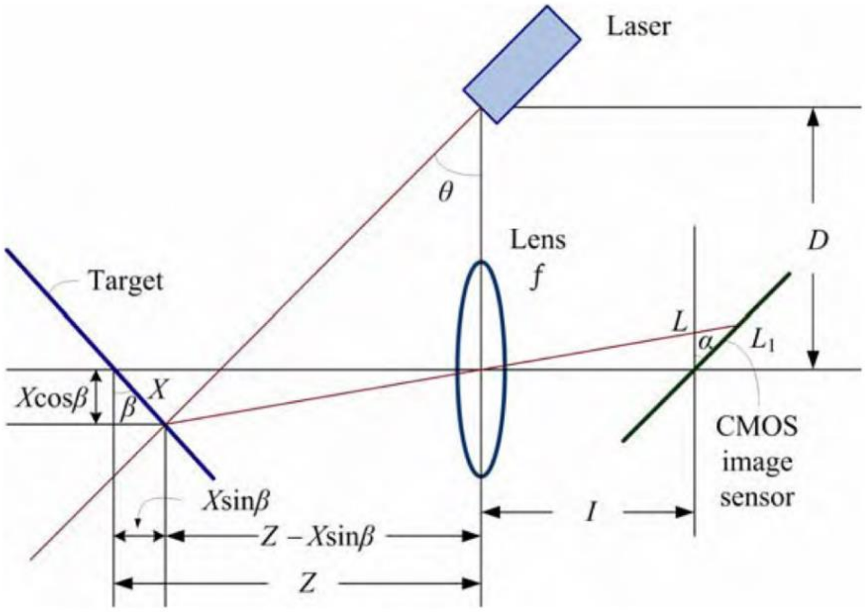

Figure 5. Triangulation measurement model.

It can be seen that the imaging system is mainly composed of laser, lens and CMOS image sensors. Ideally, set the tilt angle of the sensor α and the tilt angle of the target β to 0. The distance Z between lens and target can be simplified without considering the angle.

$$Z = \frac{DI}{I\cot\theta - L_1}$$

In this equation, D is the distance between the laser and optical axis of lens. f is the focal length of lens, which almost equal to the image distance I. The formula of resolution $|dZ|$ is obtained by differentiating the distance Z according to the measured distance:

$$|dZ| = \frac{Z^2}{ID}dL \approx \frac{Z^2}{fD}dL$$

According to the resolution data affected in the model, the resolution of the range system can be improved by increasing the focal length of the lens, increasing the distance between the sensor and the laser, and making the pixel of the CMOS image sensor smaller. The experiment is carried out in an ideal state, but in practical applications, noise is inevitable. In order to improve the signal-to-noise ratio of the system, a narrow band pass filter is usually installed in front of the CMOS image sensor to filter the visible light [12]. The targets in the application can be moving cars, static trees or walls, etc., but the accuracy of dynamic ranging is more important than static ranging, and it is also more difficult to achieve. The normal speed of vehicles on the expressway is about 90-120 km/h. In order to ensure driving safety, the distance between vehicles shall be at least 50 meters. Therefore, when the distance between vehicles is less than 50 meters, the range system should accurately measure and convey relevant information to the driver. In application, 100 sets of distance data are measured every 5 meters within the range of 5 meters to 50 meters, and the standard deviations are all less than 1 meter, which ideal in practical application [12].

3.3.2. Passive range finder. In the dark night, the driver's ability to judge the distance from the vehicle in front is greatly reduced, so accurate ranging is very important. Under this condition, the two rear

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lamps of the front vehicle are the most effective optical signals, so the image sensor can estimate the distance between the two vehicles based on the rear lamps. In distance measurement, by selecting the information in two white lines, the distance of vehicles ahead in the same lane can be estimated more accurately. The experimental model of passive ranging is almost the same as that of active ranging, except that the target becomes a two beams laser of taillights [13]. The dark environment greatly weakens the image resolution, and any irrelevant information in the image may affect the sensor's judgment of distance. Due to the movement or relative movement of the photographic object, the generated image is likely to be blurred. In order to maximize the image quality, the minimum exposure time can be calculated to eliminate the blur and maximize the shooting brightness. The image definition can be adjusted by controlling the gain level, and the background noise can be significantly reduced by controlling the exposure time [12]. When the exposure time is long, not only the taillight of the front car can be seen, but also the surrounding street lights and warning lights will be exposed, which may lead to abnormal ranging. Therefore, the CMOS image sensor shields the surrounding light by adjusting the exposure time to minimum value, leaving only the light of the taillight, so as to achieve the purpose of correct ranging.

This method has limitations. The measurement accuracy will change as the vehicle distance changes. Due to the objective fact that the objects near are large and far away are small, the signal size of the two taillights of the vehicle in front will change with the distance， by the way the signals sent by taillights of different models of vehicles are different due to different shapes. The experimental results show that the farther the distance between vehicles is the more accurate the measurement will be. Consider that the moving track of the vehicle is not straight when turning, it may affect the accuracy of ranging. However, the relative angle generated during turning is very small in practice and the error generated will not exceed 1m, so turning will not affect the work of the passive rangefinder. In addition, the passive rangefinder can be integrated with the active rangefinder in a ranging system, and the active rangefinder can help the system accurately identify the taillight signal to achieve better ranging effect.

4. Conclusion

CMOS image sensor has developed rapidly in the image sensor market since the 1970s with the advantages of low cost, high integration and fast data processing. Now it has become the most popular imaging equipment and will continue to be widely used in many fields in the future. Not only that, companies such as Sony and Smart Sence are of great significance for the application and technological innovation of CMOS image sensors, promoting their development in the imaging field. In the field of aerospace, the advantages of CMOS image sensors in extreme environments are explained by introducing their four characteristics: low cost, radio resistance, miniaturization and integration, and their substantive comparison with CCD is made through these characteristics which shows that the performance of CMOS is better than that of CCD. And the interdisciplinary combination of CMOS can make more contributions in the field of outer space imaging in the future. In the medical field, the application of CMOS image sensor in medical field is explained by introducing the three characteristics of miniaturization, anti-corrosion and low cost. The successful application of electronic endoscope in medical field is introduced. In the future, the size of CMOS will be smaller, the resolution of image sensor will be higher, and it will have a more long-term application in minimally invasive surgery. In the field of automobile, active and passive range finder which use trigonometric ranging method are mainly introduced. CMOS image sensors have two key functions: region selection and gain control, so as to achieve accurate ranging when the vehicle is moving at a high speed. Active and passive ranging system also has great development potential in other measurement fields.

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All the authors contributed equally to this work and should be considered as co-first author.

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