Advanced Sensing Technology and Its Future

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ABSTRACT

This paper describes the requirements and recent developments of imaging technologies for manufacturing, authentication, agriculture, healthcare and more. The high SNR and real-time sensing toward edge sensing and control as well as data learning is important in the era of big data. Recent technology development toward advanced semiconductor manufacturing is also presented.

1 Introduction

Data sensing using image sensors has become indispensable in our daily life as in object recognition, authentication, condition monitoring, autonomation in various applications. On top of the photography applications, image sensors are going to be the key data sensing device in the era of big data.

Semiconductor industry is expanding its world-wide market volume as well as its importance in economic safety. Technologies to rapidly and precisely manufacture semiconductor devices are the keys to contribute to the advanced semiconductor development. Real-time and in-situ high precision data sensing and control during the wafer process is important for this purpose.

The sensing technology can be applied to many other applications such as automobile, industrial, healthcare, agriculture, environment fields. Although the big data computation scheme maybe somewhat similar in various applications, the various sensors must be developed depending on the sensing targets. Consequently, the key performances and technologies should be explored.

2 Technology requirements

For the sensing applications, image sensors are expected to capture valuable information or meta data under limited power consumption. Recent applications of image sensors capture physical quantities such as range/distance, wavelength, absorbance/transmittance, polarization, object patterns and dynamic movements thereof, through various imaging methods. In order to utilize the imaging data, high precision and sufficiently high speed and resolution are the key performances. Some applications employ active light sources such as time-of-flight range imaging, authentication in smart devices, multi-spectral imaging, absorption imaging and so on. Thus, co-optimization of image sensors and optics including light sources is also important. Among various image sensor performances, the precision or SNR should be high enough such as 70 dB, comparable to those used in the analytic equipment. Speed requirement varies with applications, for the real-time sensing and control in manufacturing and machine vision applications the framerate should be around 1 Kfps or higher.

3 Key Technology Developments

Various wavelength is expected to be utilized based on the imaging targets. For the image sensor performances, a wide spectral response, a high sensitivity and a high robustness toward strong light irradiation are indispensable. To maximize the full capacity of Si as photodetectors, Si photodiode structure and its integration technologies to achieve high sensitivity and robustness toward UV-light waveband as well as toward near-infrared-light waveband have been developed [1]. Furthermore, soft X-ray detector development is undergoing using back-side-illumination (BSI) structure toward next generation acceleration facility under construction at Tohoku University [2].

The light intensity varies depending on the applications. Thus a wide dynamic range and high SNR are necessary performances. To achieve maximum SNR compatible to analytic equipment, the key is to increase the full-well-capacity (FWC) in a limited area. A wide dynamic range multi-stage lateral-overflow integration architecture with high density in-pixel capacitor integration technology has been developed for this purpose, achieving over 20 Me^- FWC and 70 dB SNR [3-4].

For the high-speed performances, a voltage-domain global shutter imaging architecture with pixel-wise memory bank has been developed also utilizing high density Si trench capacitors. Depending on the applications, over 100 Mfps high-speed image capturing is demonstrated [5]. Recently a TOF imager was developed using these key technologies [6].

4 Going Forward

In-pixel signal storage and frontend signal processing are important to enhance valuable signal extraction efficiency [7]. Low power signal storage and judgement is important. In recent years, digital pixel sensors using in-pixel ADC are extensively studied. For this architecture, stacking integration with advanced logic node becomes so important [8]. Furthermore, integration of advanced memories into pixel maybe another possible structure.

5 Conclusions

Sensing technology using image sensors toward various applications were overviewed and advanced high precision high-speed imaging technology development was presented.

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