【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Engineering)

Title of Project : Ultra Highly Time Resolved Imaging Devices Using Lateral Electric Field Controlled Charge Modulators and Their Applications

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Research Area : Semiconductor Devices, Mixed-Signal Integrated Circuits
Keyword : Electronic equipment, Smart sensor, Imaging device, Time-resolved imaging

【Purpose and Background of the Research】

In this study, we investigate ultra highly time resolved imaging devices with sub-picosecond time resolution and high spatial resolution for detecting very weak light signal such as fluorescence from a single molecule. A new high-speed charge modulator so-called the LEFM (Lateral Electric Field controlled charge Modulator) is proposed for the ultra highly time-resolved imaging. This semiconductor-based technology will bring significant innovation to time-resolved imaging by the nature of parallel acquisition of signals, while the conventional time-resolved imaging typically use a point detector and mechanical scanning system.

The purpose of this study is to demonstrate the significance of the LEFM in biological, medical and industrial applications and contribute to the promotion of industries on imaging and optical measurement systems by the practical use of the developed technology.

【Research Methods】

The LEFM is a high-speed charge modulation device that uses lateral electric field created by a set of gates arranged along the channel of photo-carrier transportation. The LEFM configurations include one-tap, two-tap and multiple(more than three)-tap modulators depending on their applications. To investigate the optimal conditions, structures and dimensions of the LEFM pixels for achieving the sub-picosecond time resolution, a test element group of the LEFM pixels with different designs and parameters and small LEFM pixel arrays will be implemented and tested.

The results of the fundamental study on the LEFM pixels will be used for the implementation of a fluorescence lifetime imaging microscopy (FLIM) chip and the application of the implemented FLIM chip to tumor detection using the lifetime of auto-fluorescence of living cells will be demonstrated.

The LEFM-pixel technology can be used for many attractive applications including fluorescence correlation spectroscopy (FCS) and time-of-flight (TOF) range imaging with sub- millimeter resolution. Developments particularly using the multi(>2)-tap LEFM-pixel technology for these applications will be significant topics in the latter term of this research.

【Expected Research Achievements and Scientific Significance】

The investigation of the LEFMs as a new technology for time-resolved imaging is significant as a scientific research. The significance lies in the paradigm shift of time-resolved imaging from point-detector based to area-detector based. This area imaging device will be one of key technologies in next-generation biological and medical imaging tools. The tiny imaging chip can be implemented into an endoscope and it will be a powerful tool for in vivo detection of tumor. The application of this new technology for time-resolved imaging will be expanded in the near future to many different fields such as FCS, Raman spectroscopy, near infrared spectroscopy and TOF-based 3D imaging systems.

【Publications Relevant to the Project】

・Z. Li, S. Kawahito et al.,"A time-resolved CMOS image sensor with draining-only modulation pixels for fluorescence lifetime imaging," IEEE Trans. Electron Devices, **59**(10), pp. 2715-2722, 2012.
・S. Kawahito et al., "CMOS Lock-in Pixel Image Sensors with Lateral Eelectric Field Cotrol for Time-Resolved Imaging," Proc. Int. Image Sensor Workshop, pp. 361-364, Snowbird, 2013.

【Term of Project】FY2013-2017

【Budget Allocation】151,100 Thousand Yen

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