Research on Organic-Inorganic Hybrid Optical Image Sensors using Green-Sensitive Organic Photodiodes

Form 3

Abstract

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Growing need for high resolution sensors in imaging devices has strongly demanded new device schematic concepts to improve the resolution of complementary metal oxide semiconductor (MOS) image sensors (CIS). One solution is to stack light-absorbing layers 3-dimensionally (3D), so as to increase the effective light detection area per each pixel. Silicon (Si) and lead sulphide quantum dot based CISs have been reported, in which blue-, green-, and red-light absorbing layers are stacked. However, these 3D inorganic CISs could not operate enough to show vivid color images due to obscure color absorption. Only an organic photodiode (OPD) can be used for the top layer on Si CISs because organic materials can be designed to absorb only a specific range of wavelengths of incident light. Especially, green light selectively absorbed organic diodes could realize double as the resolution of an image sensor because the number of green pixels in the image sensor become twice than those of the others color's pixels and the green light is in the middle of RGB visible wavelength, so the underlying Si CISs can detect red and blue signals without losing the incident light intensities.

To address green absorption OPDs (G-OPDs), a quinacridone derivative as donor and boron subphthalocyanine chloride as acceptor were applied in OPDs with transparent electrodes. The OPDs exhibited a low dark-current density (Jd) of 53 nA/cm2 and a high external quantum efficiency (EQE) of 41.2% in the green color region under a reverse bias of −3 V. Secondly, an intramolecular donor-acceptor-type merocyanine dyes as donor and C60 fullerene as acceptor were applied in OPDs. The G-OPDs showed a lower Jd of 0.106 nA/cm2 and a higher EQE of 48.6% at wavelength of 553 nm under −3V. The effectiveness of the G-OPD was demonstrated by obtaining full color image using 5 mega pixels camera containing the organic/Si hybrid CIS.

When organic components are integrated, the hybrid CISs must be carefully encapsulated to protect the environmentally sensitive organic materials from the degradation by water and oxygen. A new encapsulation material consists of two different metal oxides stacked in bi-layer thin film architecture was developed. By the application of the new encapsulation method, the overall device stability at 85 °C and at 85% relative humidity exceeded 1000 hours without observable decrease in the EQEs and with small Jd deviations within 3%.

In order to develop drive circuits for future optical image sensors mounted on glass or flexible panels, solution-processed amorphous zinc oxide (ZnO)-based TFTs were developed. The TFTs have excellent transfer characteristics with a saturation mobility of 6.57 cm2/V·s, a threshold voltage (Vth) of −0.30 V, and an inverse subthreshold slope of 0.15 V/dec. The TFTs showed only a 2.16 V shift in Vth under the long-term stresses of temperature, gate and drain voltages. Therefore, the System on Plastic (SOP) technology can effectively relax the limit on the pitch between connection terminals to be suitable for high-resolution electronics. Furthermore, eliminating peripheral circuits allows more flexible in the design of the display system.

I have researched new green organic light absorbing materials and organic diodes with high absorption and green color selectivity and fabricated the world's first 5 mega pixel CMOS image sensor. In addition, the protective layers with excellent protection and reliability of organic devices by utilizing the multi-layer thin film encapsulation technology for organic image sensors have been studied. The present study is expected to pave the way for the development of not only color image sensors in mobile cameras with higher spatial resolutions, but also multifunctional biometric image sensors in the next generation, i.e., security authentication, health care and so on.

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