Luna Optoelecronics Inc.
Camarillo, California (805) 987-0146 x155

PHOTODIODES AND AVALANCHE PHOTODIODES

Increased functionality and integration are driving strong growth in the OEM applications for these critical photonic components.

Silicon photodiodes are used to convert light into an electrical signal (voltage or current). As a result of solid state reliability, low cost and volume manufacturing, these devices are used in virtually every type of OEM photonic application. Some disparate examples include semiconductor test and measurement, spectroscopy, biomedical assay and diagnostics, and of course telecom.

Photodiodes fall into two broad classes: PIN photodiodes and avalanche photodiodes. The PIN photodiode is a very mature product, offering the advantages of inexpensive, repeatable, volume fabrication in addition to flexible packaging options. The main advantage of the avalanche photodiode is its internal gain, which can be 300X or higher. This enables the avalanche photodiode to be used in low light level applications, traditionally dominated by the photomultiplier tube (PMT). Despite their long history of use, both types of photodiode are currently the subject of vigorous, ongoing product innovation.

The past decade has seen enormous R&D efforts targeted at large area avalanche photodiode (LAAPD) technology. This has yielded a wider range of mature products supporting the specific needs of a diverse range of applications, from flow cytometry to nuclear physics and retinal mapping. Not surprisingly, LAAPDs now comprise the fastest growing photodiode market segment.

OEM applications are adopting LAAPD devices for several reasons. Unlike the PMT and other vacuum tube technology, the LAAPD is a compact, rugged, solid state detector. It offers a much wider spectral response: from the UV through the near-IR. The LAAPD also has a low noise floor and up to 6 decades of linear response. Moreover, this noise floor can be lowered even further by an integral thermoelectric cooler, which also eliminates any effects due to changes in ambient temperature. Finally, the LAAPD has a very high quantum efficiency (up to 90% in the visible, over 100% in the deep UV) and draws much less current than a PMT. While the typical PMT still offers greater gain, the majority of applications simply don't need detector gains any higher than a few hundred.

One of the most important recent developments in LAAPD technology is wider spectral range. This has enabled the LAAPD to penetrate many deep UV applications, particularly those involving 157 nm excimer laser radiation. Here the critical advantage of the LAAPD is its deep depletion region. This eliminates performance degradation due to solarizing, which is a problem for PIN photodiodes and other solid state detectors in the deep UV. A typical application here is process monitoring and wafer QC in next generation microlithography.

Luna Optoelecronics Inc.
Camarillo, California (805) 987-0146 x155

The other significant technological breakthrough is the development of multi-element LAAPD devices; quadrant detectors are already appearing in end user applications, with linear arrays expected to reach the market by the middle of this year. These devices enable position sensing or multi-channel detection. Importantly, these multi-element LAAPD arrays exhibit no cross-talk between channels, which is a common limitation with multi-anode PMTs. Typical applications include Positron Emission Tomography (PET) and nuclear imaging.

The greatest market growth for LAAPDs will probably occur in smaller devices, with active areas in the 3-5 mm diameter range. Smaller area results in lower capacitance, and hence faster speed. Moreover, multiple devices can be produced from a single wafer, resulting in lower unit cost, which is attractive for cost-sensitive applications. A key application for these devices is multiple channel medical diagnostics.

The most prominent trends in PIN photodiodes are in integration and packaging rather than the detector itself. This is in response to a steady increase in market demand for OEM photodetection modules that feature higher levels of optical and electronic functionality integrated within a single package. These photodetection products can be as simple as a single PIN photodiode in a TO can with a glass diffuser input window, or as complex as a multi-element detector, with optical filters, and extensive signal processing electronics.

The combination of several new technologies are enabling ongoing reductions in both the size and packaging complexity for these products. For example, the same technologies used to support miniaturization of consumer electronics (ball grid arrays, flex circuits, etc.) are supporting similar miniaturization of photodiode assemblies. Another major advance has been the direct deposition of multilayer optical filters directly on the actual photodiode substrate, as embodied by the FILTRODE® series from Luna Optoelecronics . This is particularly useful in laser based systems, where it increases the detector's ability to discriminate the signal from ambient light. Typical applications include laser scatter based metrology and bar code reading.

Despite its long history, photodiode technology remains a field active of development, as well as an area of dynamic market growth. Furthermore, the tremendous diversity in applications insulates the overall photodiode market from fluctuations in any specific segment.