二· 項目簡介

(*項目所屬科學技術領域、主要技術內容、授權專利情況、技術經濟指標及應用推廣情況*)

Wireless UV flame detectors for fire-safety applications

Introduction

Property management, no matter it is for cultural heritage, business buildings and residence, is entrusted with the responsibility of protecting and preserving the buildings, stored properties and occupants. A multisensor system is usually equipped to minimize adverse impact due to climate, pollution, theft, vandalism, insects, mold and fire. Because of the speed and totality of the destructive forces of fire, it constitutes one of the more serious threats. Thus, fire detection is one of the most important issues.Together with other industrial applications such as the combustion control for industrial boilers, a potential annual market of around USD130 Millions for fire sensors was predicted in the Micro and Nano Technology (MNT) gas sensor forum held in December 2006. The most commonly used fire detector in fire safety sector is the smoke detector. However, smoke detectors suffer a high false alarm rate, slow response in open area and unsuitable in air polluted areas such as car parks.Being able to compensate the above disadvantages of smoke detectors, flame detectors have recently attracted much research and development attention.

Flame detectors use optical sensors working at specific narrow spectral bands to record the incoming radiation at the selected wavelengths. The signals are then analyzed using a predetermined technique (flickering frequency, threshold energy signal comparison, correlation to memorized spectral analysis and so forth). Flame detectors are available in a number of sensor types. The most common sensor types include ultraviolet (UV) detectors or UV/IR (Infrared) detectors. UV only flame detectors work with wavelengths shorter than 300 nm (solar blind spectral band). They detect flames at high speed (3-4 milliseconds) due to the UV high-energy radiation emitted by fires and explosions at the instant of their ignition. UV/IR detectors compare the threshold signal in two spectral ranges and their ratio to each other to confirm the reliability of the fire signal, minimizing false alarms. Since the technology of IR radiation detection has been well established and mature today, thus the short-wavelength UV detection is the core technology needed to be further developed for flame detectors.Flame detectors are therefore gaining more attentions in recent developments.

The technology for UV flame detection currently adopted in the market is based on the photoelectric effect of metal and the gas multiplication effect, similar to the Geiger-Müller (GM) counter (for example, products from Hamamatsu and Senseware). A quartz tube filled with an inert gas conducts electricity when a photon of wavelength between 185 and 260nm of a flame temporarily makes the gas conductive. The tube amplifies this conduction by a cascade effect and outputs a current pulse. Disadvantages of this technology include that the detection system is 1) bulky; 2) expensive (a pulse counter is needed for signal readout); 3) hard to maintain (high-voltage operation usually causes a lifetime in the order of only

10,000 hours); 4) Inter-interfering (the discharge tube itself emits ultraviolet radiation in operation. It doesn't allow the use of two or more flame detectors of this kind at the same time in close position since they may optically interfere with each other).

Besides the flame detection, the installation of fire alarm systems may be constrained. For example, in ancient and historic buildings, the construction works of cable layout for wired fire alarm systems may damage the building architecture and decoration, which are usually unrecoverable. Wireless Sensor Network (WSN) with flame detectors as sensing nodes that are self-organized to real-time gather environmental data and detect abnormalities in the monitoring region, can alleviate this problem with no wiring network installation. However, it is still rare to have such WSN node in the world.

Invention Summary

This project is about wireless UV thin film flame sensor integrating sensing, thin film and wireless communication technologies. Considering UV thin film detector, a lot of effort has been recently devoted in the research of solar-blind UV thin film detectors based on wide-bandgap semiconductors such as MgZnS, AlGaN, diamond, Ga_2O_3, $LaAlO_3$ and ZnMgO. Among these materials, those based on ternary alloys would face difficulty achieving the desired composition in mass production, while diamond detector is very difficult to make and costly in fabrication. The Ga_2O_3-based detectors reported so far seem to require the apply of a voltage bias for operation and a post-growth thermal annealing for improving their photoresponse characteristics, also the need of the use of oxygen source in their production could increase the damage rate of the fabrication facilities due to unintentional oxidation.

Against this background, the key invention of this work is based on the use of a binary compound material, MgS, as the active layer of the detector, so the photoresponse spectra of the produced detectors can remain almost identical even for a large-scale production, without being affected by the consumption of the stored sources in the growth system. The invented MgS solar-blind detector can be operated in zero-bias mode without the need of an external power supply and additionally, MgS is an environment friendly material. The response cutoff of the invented detector is located at about 250nm, which is an ideal value for solar-blind flame detection.

As an application of the above invented UV flame detector,a prototype WSN node is composed of UV flame detector, a current-sensitive front-end including 120 dB high gain current-to-voltage amplifier and a logarithm converter and; a 2.4 GHz ZigBee wireless transceiver. As the flame detector is passive, the wireless connectivity together with signal process consumes only 360 mW from 3.3 V supply during operation. The performance of a prototype sensor node was verified when the luminous flame was imaged onto the sensor node with different angles and distances enabling effective fire safety applications. A self-power UV sensing System-on-a-Chip (SoC) is also designed for future autonomous operation. It consists of a power management unit and a UV sensing unit including a current preamplifier, a current-mode successive approximation Analog-to-Digital Converter. Using standard 0.35 μm CMOS process, CMOS photodiodes for solar energy harvesting can be implemented in the same die without any post-processing.

US Patent

According to the novelty and utility of the invention of relevant sensor, particularly the simply fabrication compared with ternary compounds, low production cost and so forth, a provisional US patent US 61/457,896 was filed with the US Patent and Trademark Office on 30 June 2011.

Technical and Commercial Aspects

Technical aspects: A UV detector comprises an active layer that is grown directly on a substrate followed by a further deposition of a thin metal layer as a transparent Schottky metal. a) Cutoff wavelength below 250 nm; b) Substrates include GaAs (100), (111)B or other orientations; c) Active layers are Rocksalt, Wurtzite or other phases of MgS; d) Schottky metal is Au, Cr, Al; e) Deposition method for the active layer is molecular beam epitaxy; f) Standard analogue output being compatible with conventional analogue to digital converter technology for system integration of different applications.

Commercial aspects: Competitive benefits comparing to existing products/technologies include low cost, long lifetime, compact in size and no inter-interfering. Detector's throughput in a 2" wafer can be as high as 14,000 and it is cost effective to compete in the fire safety market. Compared with GM tube, a) the price of GM tube with drive circuit is over USD50 while the cost of the above sensor is estimated to be few US dollars; b) Because detector isn't operated under high voltage as GM tube does, its lifetime is much longer than 10,000 hours traditionally limited.

Usage Promotion and Training of Students

In addition to conference papers, 4 IEEE/AIP journal papers have been published for academic promotion. This project has 3 MSc graduates and supported 5 Final Year Project, 3 MSc and 2 PhD students who will complete their studies in one or two years. The project attracts 2 companies to explore its application in telecommunication and cultural heritage conservation, they are China Comservice (Macao) Limited and; SoftFabrique Limited. SoftFabrique supports us to develop a iPhone Apps titled "UV Eye" for cultural heritage conservation in Macao. This is indeed the first Macao's software platform of fire monitoring of Churches, Temples and so forth. Apps "UV Eye" was awarded with "Merit Prize" by Macau ICT Awards 2011 and one of Macao's delegations for The Asia Pacific ICT Awards (APICTA) 2011 held in Thailand.