Student Paper

Multilayer, colloidal nanoparticle based devices for biological and nuclear radiation detection

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Multiple layers of colloidal nanoparticles were used to make large area, visible blind and wavelength selective, ultraviolet (UV) photodetectors [1]. Polyvinyl-alcohol (PVA) coated ZnO nanoparticles were created by a top-down wet-chemical means and deposited on quartz, glass, or GaN-based substrates [1-3]. The advantages of high sensitivity, low power consumption, and the ability of to filter out ambient light, are the result of layered nano-materials on substrates [4]. In separate experiments, these detectors were tested for both bio-fluorescence and alpha particle scintillator detection as a proof-of-concept.

A ZnO nanoparticle-AlGaN substrate photodetector was placed in an intrinsic bio-fluorescence experiment with a 280 nm UV LED with a total optical power of 158 µW. E-coli cells, ATCC-25922, were diluted in phosphate buffered saline (PBS) solution with an initial optical density of $OD_{400-500}$=0.5. As shown in Fig.1 (a), the solution was placed in a cuvette and the LED light source was set up 90^o from the detector. The bio-fluorescence sensitivity of the PVA coated ZnO nanoparticle-AlGaN substrate bandpass UV photodetector was found to be better than a UV enhanced silicon photodiode and within two orders of magnitude to the high sensitivity of traditional photomultipler tubes (PMTs) [4]. Furthermore, to investigate the direct coupling ability of bio-fluorescence and detector as well as improve the signal over noise ratio in a more compact and better wavelength aligned system, the setup was modified for 180^o detection (Fig. 1(b)) and the detector substrate was changed from AlGaN, with cut-off wavelength at 300nm, to a much cheaper microscope glassslide, with a cut-off wavelength at 295nm. The new setup improves the signal over noise ratio from 1.5 to 7 and distinguishes the E-coli sample up to 1/8 dilution of the original sample, as indicated in Fig. 2.

A similar experiment was conducted to detect light emitted from a YAP:Ce scintillator under alpha particle radiation. The direct coupling of alpha particle scintillator material with a visible blind nanoparticle photodetector was demonstrated. The experimental structure is shown in Fig. 1(c). A YAP:Ce scintillator (crystal of YAlO3: Ce) has favorable characteristics such as relatively high scintillation efficiency (40% of NaI (Tl) light output), fast scintillation decay time (25 ns), chemically inert and high melting point (1875 ℃) [5-8]. In addition, the emission spectral of YAP:Ce is in the UV range with the peak at about 370nm [9]. This emission wavelength beyond the visible is important to differentiate the detection signal from ambient light and it aligns well with ZnO's detection wavelengths (Fig.3 (a)). As presented in Fig. 3(b), an UV generated current (under alpha radiation) to dark current ratio of about 3 at -20V bias was observed in the integration of YAP:Ce scintillator and PVA-coated ZnO nanoparticles.

These two proof-of-concept experiments demonstrate broad and flexible applications of multiple layers colloidal nanoparticles based devices.

References

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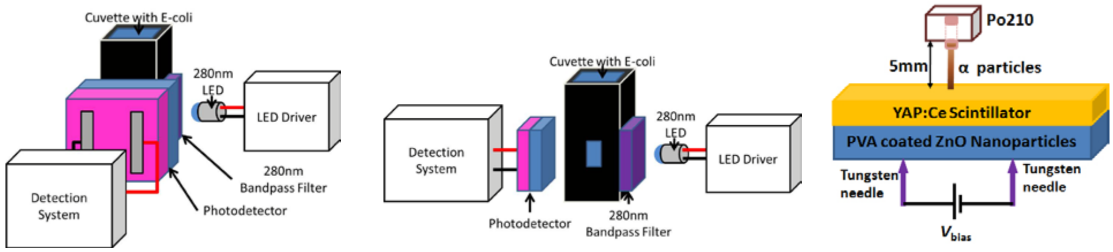
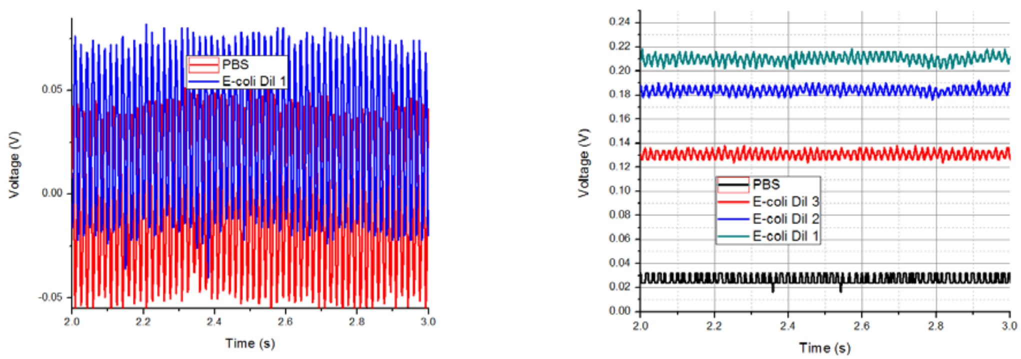


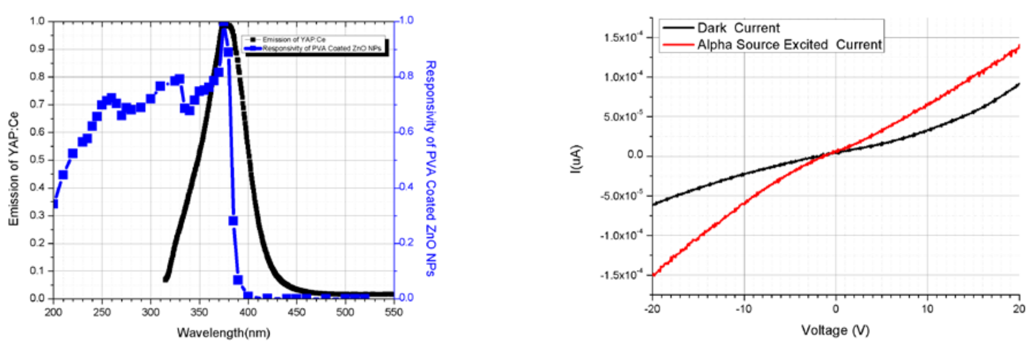
(a) (b) (c)

Fig.1 (a) 90^0 bio-fluorescence system, (b) 180^o bio-fluorescence system and (c) experimental structure of scintillator device.



(a) (b)

Fig. 2: Bio-fluorescence measurements for (a) a ZnO nanoparticle-AlGaN substrate photodetector with 90º setup compared with (b) a ZnO nanoparticle-glass substrate photodetector with 180º setup with respect to concentrations of E-coli (ATCC-25922) following excitation by 280 nm



(a) (b)

Fig. 3 (a) Spectra alignment and (b) I-V plot of integration of YAP:Ce and PVA coated ZnO nanoparticle used in alpha particle radiation detection (P0210, 386µCi).