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Photoconductive Gain Effect: detection of ionizing radiation by highly defective semiconducting thin films-based photoconductors

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Photoconductive gain is a physical phenomenon typical of photoconductors, where a highly defective semiconducting photoactive material is between two ohmic contacts. Such trappingactivated mechanism amplifies the high energy radiation-induced current by a factor G, leading to e quantum efficiency exceeding 100% and providing high sensitivity to the radiation. It occurs when radiation-generated free charge carriers accumulate and pass several times through the semiconductor between the electrodes before recombination sets in. This process of amplification is activated by the trapping of minority charge carriers and the factor G can be expressed as the ratio between the recombination time, characteristic of the trapped states, and the transit time of free moving carriers [1].

Enhancing sensitivity and achieving higher gain are commonly the research focus for photoconductors. In the last years, photoconductive gain mechanism has been observed and deeply studied for the detection of both visible light and ionizing radiation by several semiconductor-based devices such as organic [2]–[4], nanomaterials [5]-[6] and also perovskites (e.g. Cs3Bi2I9 [7],(CH3NH3)3Bi2I9 [8], MAPbBr3 [9]). In all these cases, the common element is the presence of ohmic contacts and a highly defective active material. In particular, a trap-states, interfaces and doping engineering approach have been adopted to boost the gain factor and enhance the sensitivity [10].

Recently we modelled the photoconductive gain mechanism in Organic Field Effect transistor X-Ray direct detectors adopting several strategies and tuning different parameters to reach a full comprehension and control of this effect [11]. Besides, we employed a new technique called Photocurrent Spectroscopy Optical Quenching using both the X-Rays and visible light to study and identify the electrical traps in organic semiconductors which activate the photoconductive gain effect under ionizing radiation.

In this work we will discuss in deep all the advantages related to the presence of the photoconductive gain mechanism but we also highlight the main limits it imposes. In particular, we will focus on the most relevant challenges related to the presence of the gain and that have to be overcome to target the employment of these devices in real applications.

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