MATEC Web of Conferences **5**, 04043 (2013)
DOI: 10.1051/matecconf/20130504043

Influence of metal contacts on the electrical properties of a UV-MSM photodetector

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Abstract. We have developed a two-dimensional theoretical model. This model allowed us to characterize the MSM photodetector based ZnO. It also allowed us to simulate the dark current and photocurrent of the device with different dimensions of the metal contact of structure. The simulation results were agreed with those of the experiment. We have identified the influence of geometry parameters of the metal contact on the dark current and also on the photocurrent. Calculating the ratio (photocurrent / dark current), allowed us to find the best values of finger width w and finger spacing s of the metal structure leading to a low dark current and at the same time a better absorption of the incident light. The best performance of MSM PD are obtained for the following values s = 14 μm, w = 12 microns. These values have enabled us to obtain a dark current of 25nA and a photocurrent equal to 0.78 μA at a 3V bias.

1. INTRODUCTION

The photodetector metal-semiconductor-metal (MSM Pd) with the structure of interdigital contact is a good candidate for optoelectronic conversion to its characteristics such as its planar structure compatible with most of the semiconductor components, its low capacity and ease of fabrication and integration [1–3]. And as the numerical simulation has become an essential activity to develop technologies, and it facilitates the study of new materials and architectures of new components, we proceed to develop a theoretical model of a MSM PD based on ZnO with aluminum metal contact interdigital. The developed model is a two-dimensional drift diffusion model based on the Poisson equation, continuity equations and equations. This model introduces the two-dimensional character of the MSM PD and this allows us to study the behavior of the MSM photodetector. In this work we study the influence of geometric parameters of interdigitated metal contact on the performance of the structure. The geometric parameters (see Figure 1) are s, w, d, L and d represent respectively the distance between finger, the width of the finger, the finger length, the length of the electrode and the thickness of the absorbent layer respectively. The semiconductor used is ZnO Epitaxial layers of n-type ZnO were deposited on a sapphire substrate (0001) by magneton sputtering RF technique [4,5].

Our numerical model is applied to study the dark current and the photocurrent of a ZnO-based MSM. It therefore allow us to simulate of the current of the component as a function of the polarization. The results obtained are in agreement with experience; which proves the validity of our model [6].

Based on this model, we study the characteristics I (V) for different dimensions of the structure, to achieve a proper optimization that allows for the minimum possible dark current and the maximum possible photocurrent.

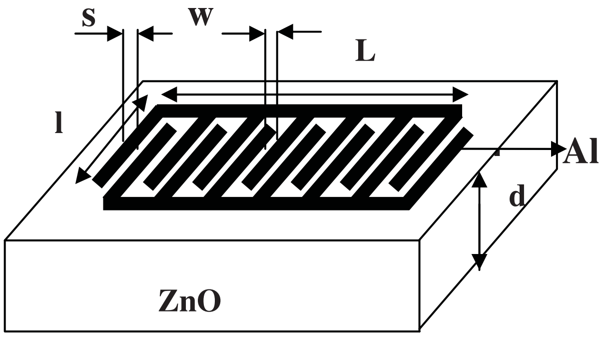

Figure 1. Basic layout of MSM structure.

2. MODELING

The calculation method is based on the following:

1. For a potential in the electrodes and a given luminosity, we begin the calculation by solving the Poisson equation starting from an arbitrary initial distribution of carriers n and p.
2. We calculate the current densities J_n J_p, using the equations of current.
3. We then use the two continuity equations to obtain the distribution of the carrier's concentrations.
4. Carriers concentrations at time t + Δt are calculated from the integration with respect to time of continuity equations and carrier concentrations n and p at time t:

$$n(x,y,ts+\Delta t) = n(x,y,ts) + \int_{ts}^{ts+\Delta t} (\nabla \cdot J_n + G - R)dt$$

$$p(x,y,ts+\Delta t) = p(x,y,ts) + \int_{ts}^{ts+\Delta t} (-\nabla \cdot J_p + G - R)dt.$$

The process is repeated as many times as necessary to achieve steady state.

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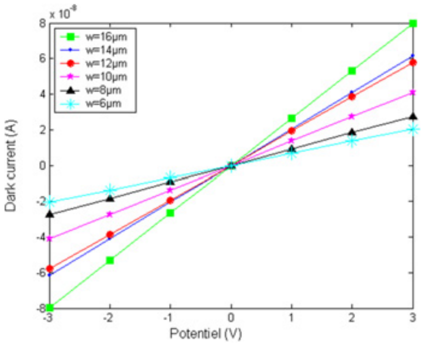

Figure 2. Evolution of dark current as a function of bias voltage for different values of the finger width for spacing equal to 10 μm.

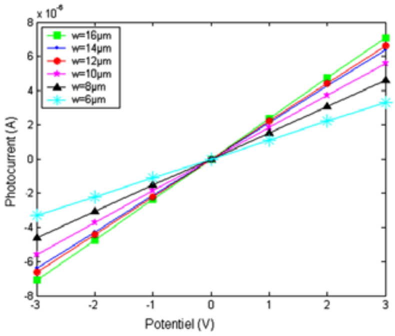

Figure 3. Evolution of photocurrent as a function of bias voltage for different values of the finger width for spacing to 10 μm.

3. RESULTS AND DISCUSSIONS

3.1. Influence of the finger width

Figure 2 shows the evolution of the dark current as a function of the variation of the bias voltage for different values of the finger width. We note that the variation of dark current depends mainly on the finger width w. In fact, the reduction in the width of the finger decreases the intensity of the current.

This is due to the current collection at the electrodes. In other words, when the finger width decreases, the collection of carriers is reduced.

The photocurrent is calculated by applying a power of 30 mW at a wavelength $\lambda = 365$ nm (UV spectrum consistent with the lamps used in the experiment). The calculation requires consideration of the photocurrent of the term in generating optical continuity equations.

Figure 3 illustrates changes in photocurrent according to the bias voltage in the interval [−3V, 3V]. The effect of the finger width on the photocurrent is exhibited by the change in the value thereof, by setting the spacing finger to a value of 10 μm.

Thus we can observe that the photocurrent depends on the change in the value of the finger width in a random manner. This result is due to the effect of dark current can be said that in addition to the photocurrent. However, it is difficult to deduce the influence of the width of the finger on the photocurrent. However we can use this result to calculate the ratio (photocurrent / dark current). We can then deduce the effect of the width of the finger and therefore arrive at the optimal.

For the same previous data and in the same way, we proceeded to study the effect of varying the spacing finger, setting the finger width of the. The results lead us to the same deduction when we need to resort to the ratio (photocurrent / dark current).

The calculation of the ratio allowed us to have the correct optimization of s and w to have a metal structure leading to a low dark current and simultaneously improved absorption of incident light. The best optimization found by this simulation and that agrees with the experiment is one where s = 14 μm, w = 12 μm.

4. CONCLUSION

we have simulated the dark current of the structure for different sizes of the metal contacts of the structure. Simulation results have been in with the experience. The variation in the values of the dimensions of the metal contacts affects the dark current and also the photocurrent. The best results are obtained for s = 14 μm, w = 12 microns, which gives a dark current of 25 nA and a current under illumination of 0.78 μA, for a $\lambda = 365$ nm and lamp power of 30 mW, the wavelength photo detector is biased at 3V.

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