Electrical Properties of Zinc Phosphide Crystals

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***Abstract* - The results of the study of electrical properties of zinc phosphide crystals are presented. S-type current-voltage characteristics were observed. The switching effect and electrical memory were obtained during the investigation of current-voltage characteristics of both monocrystal and thin film structures Me-Zn_3P_2-Me. The model of carrier generation in the great dimensional fluctuations of own internal electrical fields is discussed.**

***Keywords* - zinc phosphide, current-voltage characteristics, switching effect**

I. INTRODUCTION

Over the past several years increasing interest has been given to zinc phosphide – a semiconductor compound of the II – V group, because of its promising photovoltaic properties [1]. It has been pointed out that it would be advantageous to use as single imaging sensor with wavelength sensibility extending over both the visible and ultraviolet in spaceborne tool applications, where a wider wavelength range is accessible. Zinc phosphide appears to be a promising material from which can be fabricated such sensors [2]. Measurements of the optical properties of Zn_3P_2 in the visible part of the spectrum have indicated relatively strong photoconductivity in the interval from 9000 to 5000 Å. The energy band is approximately 1,5÷1,6 eV, the minority carrier diffusion length is approximately 10 μm and energy conversion efficiency ~ 6 percents [3, 4].

II. EXPERIMENTAL RESULTS

The performed measurements have been made on monocrystal and thin film samples of Zn_3P_2 to determine the current transport mechanism in Me-Zn_3P_2-Me structures. Sample sizes were approximately twice multiply by 10 mm. The films with thickness ranged from 5 to 15 μm were made by vacuum evaporation on different substrates. They were p-type with electrical resistivity of the order of $10^3 \Omega \cdot cm$.

The switching effect was obtained during the investigation of current-voltage characteristics both monocrystal and thin film structures Me-Zn_3P_2-Me. S-type current-voltage characteristics of these structures can be divided into three types:

1) S-type characteristics of monostable switching with extending negative resistance region. It was possible to fix any point of this characteristic by selection of parameters of circuit, such as bias voltage value, series resistance, etc. The structure surface temperature was measured and you can see the results on fig. 1.

2) S-type characteristics with two stable states and upset voltage we can obtain by connection the lower series resistance. These structures were in a low resistance state during all the time of bias application (see fig. 2).

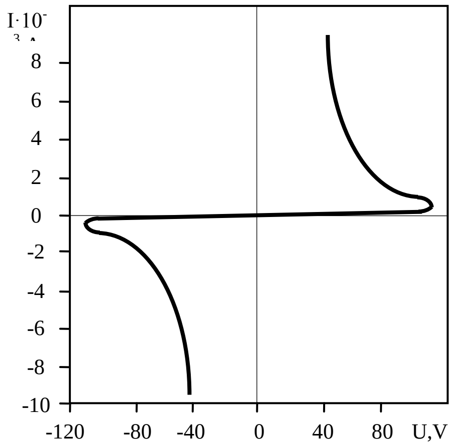

Fig.1 Current-voltage characteristic of the sample with negative differential resistance.

3) Some structures had electrical memory. They require high-temperature heating for the return to low resistance state (fig. 3).

The influence of temperature, illumination and bias voltage value has been studied to determine the switching mechanism in Zn_3P_2 structures. As a result it was obtained, that switching effect exists only in low temperature range (77-350K). The bias value decreases with increasing of temperature. The same is the illumination influence. S-type characteristics exist only at low light intensity. The switching time strong depends on bias value. Upset voltage variation within the range of 60 -180V changes switching time within the range of $10^{-3} \div 10^{-1}$ s (see fig. 3).

As a result it was determined that switching effect in Zn_3P_2 is well described by the model of carrier generation in the great dimensional fluctuation fields both on monocrystal and thin film samples of Zn_3P_2. It is possible to understand the role of occasional fields in the switching process, exponential reducing the switching time with bias value increasing and switching time dependence on light intensity. The current increasing during switching process caused the heating of material because of Joule power. Suitable results were obtained by calculations, based on electrothermal theory of switching.

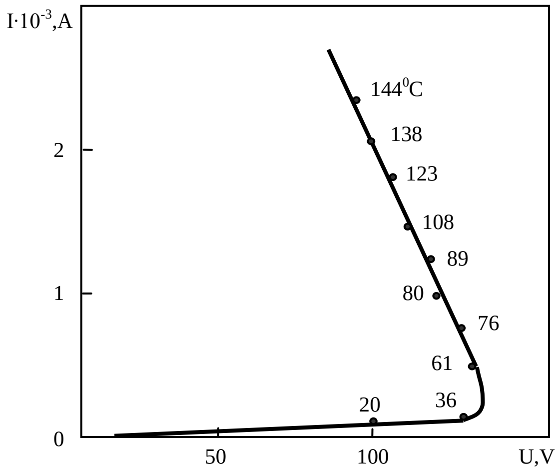

Fig. 2. Changing the temperature of the sample during the process of switching.

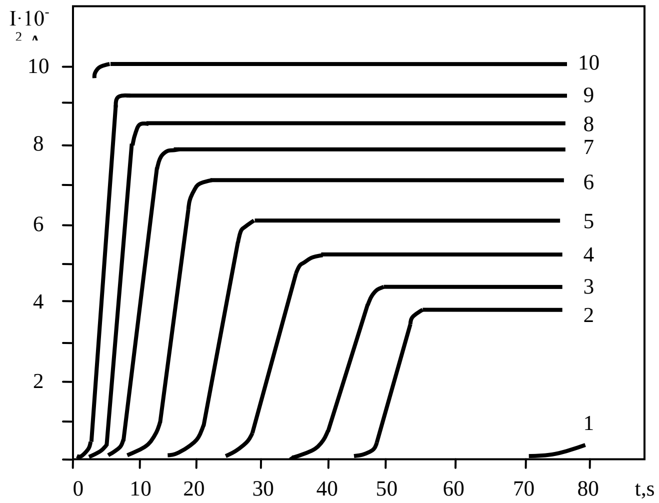

Fig. 3. Influence of the bias voltage on switching process:
U, V: **1**-55; **2**-60; **3**-65; **4**-70; **5**-75; **6**-80; **7**-85; **8**-90; **9**-95; **10**-100.

Switching effect found in Zn_3P_2 was used to create switching devices. The advantages of such devices are the employment in circuits of both direct and alternating current, the absence of hysteresis, the returning to high resistance state with circuit breakage, the possibility of variation of switching time and upset voltage by illumination. In addition the switching ratio coefficient can be changed by modification of monocrystal parameters within the range of 10^2-10^5 (see fig. 4).

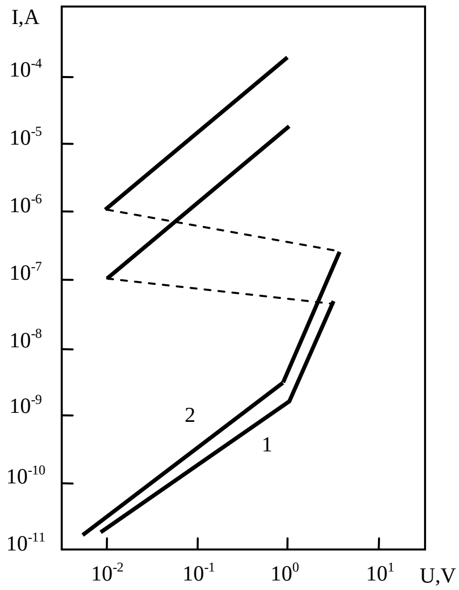

Fig.4. Current-voltage characteristics of the switching devices based on Zn_3P_2 (1) and Al- Zn_3P_2-Si-Al structure (2).

The relatively large photosensitivity of these devices and their rather flat spectral characteristics over the visible and ultraviolet wavelength range would appear to make zinc phosphide desirable detector material for radiometric applications. An additional advantage is that Zn_3P_2 photoconductive switching detectors are inexpensive devices compared to alternatives which are presently available.

III. Conclusions

The switching effect and electrical memory were obtained during the investigation of current-voltage characteristics both monocrystal and thin film structures metal - zinc phosphide. It was determined that these effects are well described by the model of carrier generation in the great dimension fluctuation fields. On the basis of the studied structures can be created radiometric detectors for visible and UV wavelength ranges.

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