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Substrate Temperature Effect on The Spectrum Emission in Superconductor Heterostructure BiPbSrCaCuZnO

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ABSTRACT

This paper shows the applied voltage effect on the superconductor substrate sample. The substrate temperature (Ts) increases the activation energy of the substrate atoms. Thus, the injecting of minority carriers (holes) increased in ZnO semiconductor. These carriers recombine with electrons of 4S1 shell for Cu atom. The recombination occurs by two ways from band to band (direct recombination) or via traps (indirect recombination). The recombination mechanisms produce photons emission in the ultraviolet and visible spectrum. The calibration between voltage and temperature achieved using Variac device. The applied voltages were 60, 65, 70, and 80 Volt, and the recorded substrate temperatures were 300, 320, 350, and 400 °C, respectively.

KEYWORDS: BiPbSrCaCuZno superconductor; substrate temperature; light emitting diode; photon emission.

الخلاصة

نبين في هذا البحث تأثير الفولتية المسلطة في زيادة طاقة تنشيط ذرات القاعدة حيث تعمل على رفع درجة حرارة القاعدة (Ts) وحقن الحاملات الأقلية في شبه الموصل ZnO. هذه الحاملات تلتحم مع الإلكترونات الغلاف S14 لذرة Cu. عملية التحام تكون بطريقتين التحام مباشر من حزمة إلى حزمة، والتحام غير مباشر عبر المصائد حيث نحصل من عملية التحام انبعاث فوتونات في مدى الأطوال الموجية تتراوح بين نهاية حافة الضوء المرئي عند الخط البنفسجي مروراً عند بداية الأشعة فوق البنفسجية UV. حيث تم معايرة الفولتية ودرجة حرارة القاعدة باستخدام جهاز Variac والفولتيات المطبقة هي (60, 65, 70, 80) Volt ودرجات الحرارة القاعدة المسجلة (300, 320, 350, 400)°C على التوالي.

INTRODUCTION

A heterojunction is created by the contact between two various semiconductor materials. Heterojunctions can be sorted as abrupt or graded and can be sorted by the kind of conductivity existing on each side of the junction. If two semiconductors have similar kinds of conductivity, then the junction called isotype heterojunction (n-n) or (n-p) type [1].

The applied voltage affects the injection of minority carriers (holes) at the interface or a diffusion length from it.

The inter diffusion effect is also present in the interface of those heterojunctions which are fabricated in elevated temperature [2].

This inter diffusion, which especially takes place at the case from heterojunction created by two compound materials, is composing elements from the semiconductors and their dopants on both sides from the interface. This may vary the abrupt nature to the heterojunction and induce dislocations in the interface [3, 4]. Super conductivity of LED used in many applications such as flash circuit, photodetector, remote control, communication application, the Spectrum analyzers, tunnel diode, and X-ray detection for CAT scanners [10].

In this paper, the ZnCuO layer fabricated and treated as a heterojunction CuO/Zn [6,8,9]. Changing the rang of the substrate temperature (Ts) of BiPbSrCaCuZnO heterostructure materials is tested to controlled LED. The role of Cu with ZnO layer system plays p-n junction and the effect of Ts on energy spectrum distribution presented within this work.

THEORY

Optoelectronic properties of heterojunctions can be classified into two groups. The first deals with generate photo current due to an absorption of photons. The second deals with emission of photons as a result of electronic excitement at heterojunction [3].

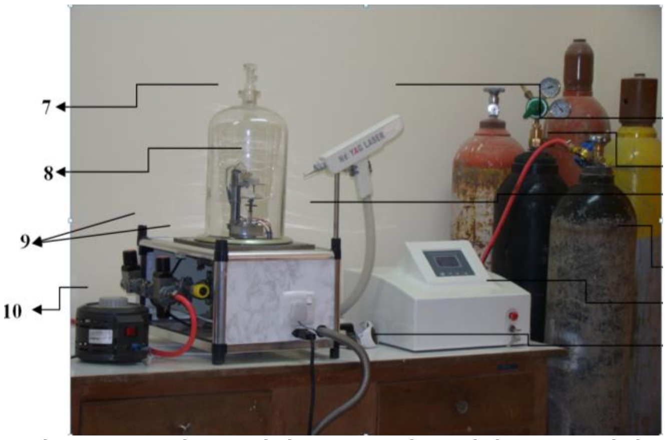
There are two important absorption procedures which often have an influence on the photoelectric characteristic of hetero junction: the creation of free electrons or holes (i.e. photo excitation from an impurity or interface state) and free electron hole pairs (i.e. electron transition of the valence band into the conduction band) [4, 5].

The free carries, generated by these processes at the interface or with diffusion length, in the two semiconductors forming a heterojunction, give rise to photo currents at the heterojunction [4].

The inverse of the semiconductor photocell is the light-emitting diode given a large forward voltage; many holes are injected across the junction into the region Cu^{+1}. When these minority carriers recombine with majority carriers in the respective regions, they lose energy and radiate photons as visible light-emitting. Diodes are widely used for digital displays in clocks and electronic device [5, 6].

EXPERIMENTAL WORK

Experimental setup of pulse laser deposition shown in Figure 1. BiPbSrCaCuZnO target mounted in vacuum chamber with 10-4 mbar, and ablated frequency by a double frequency with Q-switched Nd:YaG pulse laser operated at 532 nm, pulse duration of about 7nsec with (0.4-8 J/cm^2) energy density focused on the target to generate plasma plume. All samples were grown at Si substrate with (111). Oxygen background pressure of 2×10^{-3} mbar used.



1. Nd:YAG Laser Head. **2**. O_2 cylinder gas. **3**. Stainless steel Flange. **4**. N_2 cylinder gas. **5**. Nd:YAG laser Power supply. **6**. Flexible tube KF16. **7**. Quartz Chamber. **8**. Substrate holder. **9**. Vacuum system. **10**. Variac devices.

Figure 1. Experimental setup of pulse laser deposition.

$BiPbSrCaCu_{0.4}Zn_{0.6}O$ samples were prepared by Pulse Laser Deposion (PLD) at different substrate temperature 300, 320, 350 and 400 °C controlled by governance voltage in Variac device.

The applied voltage on substrate was 60, 65, 70, and 80 Volt and reproduce 300, 320 350 and 400 °C. This changing in voltage causes the photon emission at heterojunction.

RESULTS AND DISCUSSIONS

CuZnO sample prepared using ZnO sample to generate n-type semiconductor. The crystalline structure of the resulted sample is quartzes which permits Zn to move freely to different positions in the crystal lattice and recombined with Cu which play role to shape p-type semiconductor.

The locations of lower E_v and higher E_c are displaced in this regime. So electrons collected at lower E_v and holes collected at higher E_c. The substrate temperature breaks the bonds at heterojunction at changing voltage. Therefore, the applied voltage acts as injector for minority carrier holes which recombination with electron. All emissions wave lengths extended from end edge visible region at the violet line passes near the ultra violet region. Increasing the applied voltage produce short wavelengths or high frequencies [9, 10]. The frequencies estimated from $f = KTs/h$, where K is Boltzmann constant (K=1.38×10^{-23} J.K^{-1}), h is plank constant (h=6.636×10^{-34} J.S) and wavelength calculated from $\lambda = c/f$ where c is light velocity.

Table 1: Applied voltage (V) with TS.

V (Volt)	Ts (°C)	E=KTs (eV)	F (Hz)	λ (m)
50	300	0.025	62.386×10^{11}	4.808×10^{-5}
60	320	0.027	66.54×10^{11}	4.508×10^{-5}
70	350	0.048	72.78 ×10^{11}	4.122×10^{-5}
80	400	0.055	83.18×10^{11}	3.606×10^{-5}

The transitions between electronic states in CuZnO layer as well as recombination processing between electrons and defects levels emit photons shown in Figure 2a, b.

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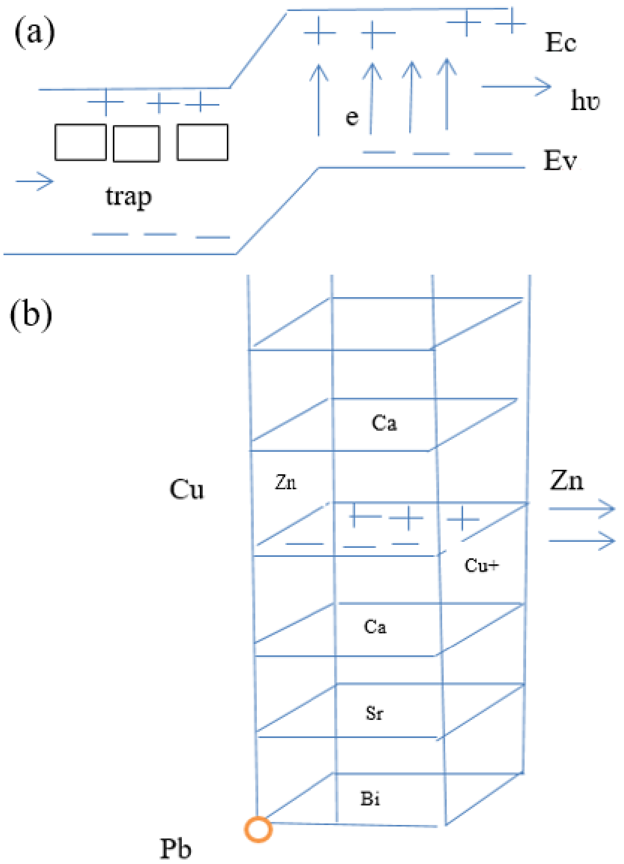

Figure 2. Schematic of the introduced method (a) expected band diagram of CuZnO (b) lattice diagram of BiPbSrCaCuZnO.

The relation between energy spectrum distribution with substrate temperature TS believed to assist the atoms to vibrate about their equilibrium positions, as well as increase transitions between electronic states. The energy spectrum distribution increase as a function of Ts, and wavelength decrease as a function of Ts, as shown in Figure 3 and Figure 4.

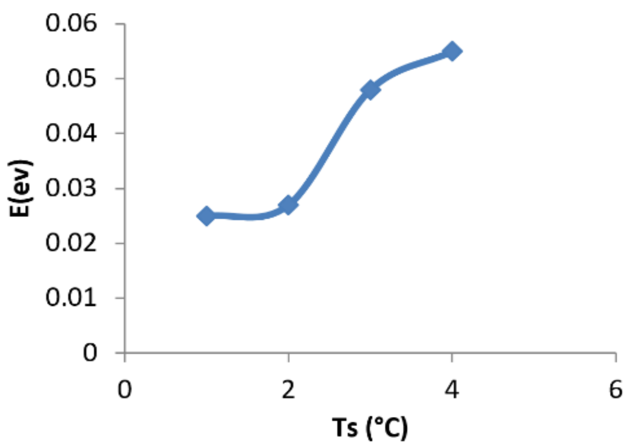

Figure 3. Energy Spectrum distribution versus substrate Temperature TS.

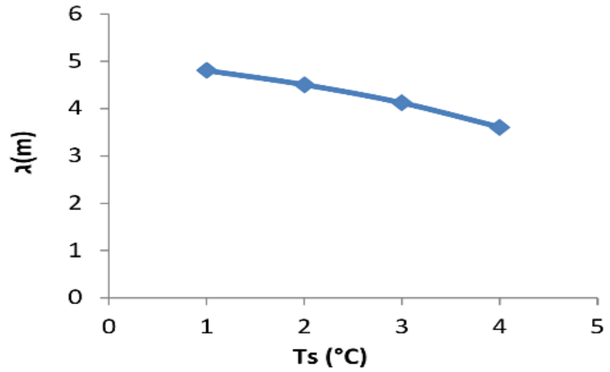

Figure 4. Wavelength (λ) versus substrate.

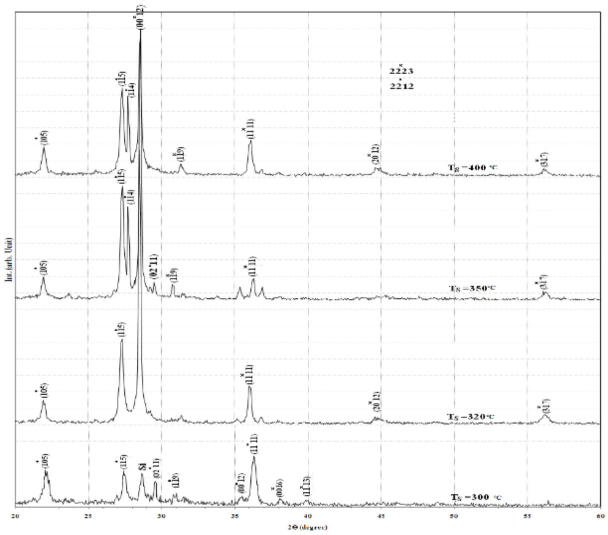

Figure 5. XRD pattern of BiPbSrCaCuZnO thin film deposited at variable Substrata temperature 300, 320, 350, 400 °C.

The inter growth phase is 2212 and 2223. Increasing Ts value does not causes re-evaporation of Bi in the film, but increase activation energy, and thus leads to grow high phases between 2212 and 2223. XRD patterns and Miller indices for specimens under study shows tetragonal structure. The effect of Ts on lattice parameters values are shown in the Table 2.

Table 2: Values of lattice parameters for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_{2.4}Zn_{0.6}O_{10}$ film deposited at different substrate temperature.

T_s (°C)	a (Å)	c (Å)
300	3.99	37.33
320	4.49	36.96
350	4.62	36.96
400	4.62	36.96

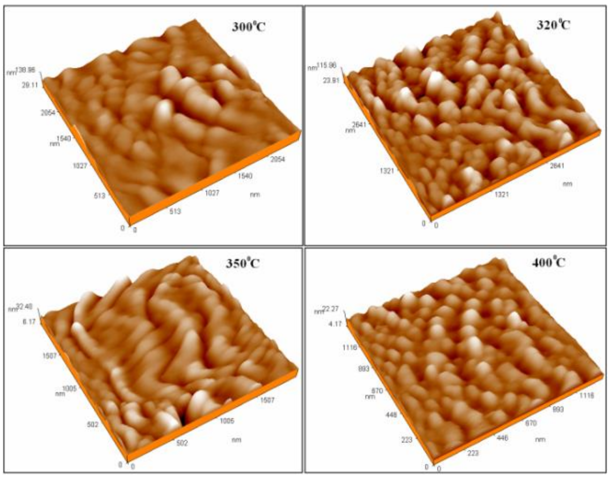

Figure 6. AFM of BiPbSrCaCuZnO films at different substrate temperature 300, 320, 350, and 400 °C.

The results revealed individual epitaxial domains possess. This can be explaining the thermal activation energy that has impact on the roughness of the film where enhance chemical bonds and increase the grains interaction. Also images show presence of the ZnO decreases the average diameter at increasing Ts.

Table 3: Values of lattice parameters for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_{2.4}Zn_{0.6}O_{10}$ film deposited at different substrate temperature.

T_s (°C)	Average Diameter (nm)
300	107.49
320	164.23
350	105.30
400	69.19

CONCLUSIONS

The applied voltage elevated substrate temperature cause break of the bonds and creation (e-h) pairs and high density of dangling bonds at interface state between CuZnO.

Some of the free carriers are move to other layers such as (Ca or Sr) layers, while another recombination with holes in CuO layer considered in two ways: direct and indirect recombination. As a result, the CuZnO layer in BiPbSrCaCuZnO superconductor thin film operates as light emitting diode (LED).

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