Çankaya Üniversitesi Fen-Edebiyat Fakültesi,
Journal of Arts and Sciences Sayı: 4 / Aralık 2005

Current-Voltage-Temperature Characteristics of $Cd_{0.73}Zn_{0.27}S_{1-x}Se_x$ Films Deposited by Spray Pyrolysis

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Abstract

$Cd_{0.73}Zn_{0.27}S_{1-x}Se_x$ films (x=0 and x=0.8) have been deposited by the spray pyrolysis method at 275±5°C substrate temperature. These films showed n-type conductivities. The electrical properties of the films have been investigated in the form of planar gold-semiconductor-gold structures. The variations of conductivities and current-voltage characteristics of these films were investigated depending on the temperature and applied voltage. Investigated films were exhibit ohmic and space-charge-limited conduction. The current temperature measurements of the films have been obtained between 257 and 320K. The activation energy of $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film is found to be higher than the activation energy of $Cd_{0.73}Zn_{0.27}S$ film.

Key Words: *II-VI Compounds, Spray Pyrolysis, I-V Characteristics, Ohmic Conduction, Space-Charge-Limited Conduction, Activation Energy.*

Özet

$Cd_{0,73}Zn_{0,27}S_{1-x}Se_x$ filmleri (x=0 ve x=0,8) püskürtme yöntemi ile 275±5°C taban sıcaklığında elde edilmiştir. Bu filmler n-tipi iletkenlik göstermektedir. Filmlerin elektriksel özellikleri altın-yarıiletken-altın düzlemsel yapı formunda incelenmiştir. Bu filmlerin akım-voltaj karakteristikleri ve iletkenlikleri uygulanan voltaj ve sıcaklığa bağlı olarak incelenmiştir. Incelenen filmler ohmik ve space-charge-limited iletim göstermektedir. Filmlerin akım-sıcaklık ölçümleri 257-320K sıcaklık aralığında elde edilmiştir. $Cd_{0,73}Zn_{0,27}S_{0,2}Se_{0,8}$ filminin aktivasyon enerjisi $Cd_{0,73}Zn_{0,27}S$ filminin aktivasyon enerjisinden daha yüksek olduğu bulunmuştur.

Anahtar Kelimeler: II-VI Bileşikleri, Püskürtme Yöntemi, I-V Karakteristikleri, Ohmik İletim, Space-Charge-Limited İletim, Aktivasyon Enerjisi.

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1. INTRODUCTION

II-VI compounds, especially CdS, CdSe, CdTe, $Cd_{1-x}Zn_xS$ etc. are of great interest because they are potential candidates in many practical applications like solar cells (Schulmeyer et al., 2005; Abou-Ras et al., 2005), optical detectors (Kandarakis et al., 2001), field effect transistors (Mereu et al., 2004) and optoelectronic devices (Yokoyama and Chen, 2001; Sharma et al., 2004). The development of low-cost solar cells depends on the exploitation of films and thus CdS, CdSe or CdTe films obtained under various experimental conditions, requires comprehensive electrical characterization (Antohe et al., 2002).

A number of film deposition methods like chemical deposition (Ortuño-López et al., 2004; Rincón et al., 2003), vacuum evaporation (Kumar et al., 2004; Subba Ramaiah et al., 2001; Antohe et al., 2002), chemical vapour transport (Mikami et al, 2005; Fujiwara et al., 2005; Ohshima et al., 2004), and chemical spray pyrolysis (Ratheesh Kumar et al., 2005; Sharma et al., 2003; Krishna Kumar et al., 2004; Su and Choy, 2000) have been used for preparing II-VI compounds.

The spray deposition method is particularly attractive because of its simplicity. It is fast, inexpensive, vacuumless and is suitable for mass production. The spray pyrolysis method used is basically a chemical deposition method in which fine droplets of the desired material are sprayed onto a heated substrate. A continuous film is formed on the hot substrate by thermal decomposition of the material droplets (Riad, 2001).

Current–voltage characteristics are an important role in the investigation of the electrical conduction of solids. In particular, various deviations from Ohm's law can be sources of information about the mechanisms of injection, generation and transport of charge carriers. Current voltage characteristics are obtained in static conditions with voltage changing stepwise.

In this work, current-voltage-temperature characteristics of $Cd_{0.73}Zn_{0.27}S_{1-x}Se_x$ (x=0 and x=0.8) films deposited by the spray pyrolysis method are investigated.

2. MATERIALS AND METHODS

$Cd_{0.73}Zn_{0.27}S_{1-x}Se_x$ films were deposited by spraying an aqueous solution containing $CdCl_2.H_2O$, $ZnCl_2$, $(NH_2)_2CS$ and $H_2NC(Se)NH_2$ 0.01M. The x value of $Cd_{0.73}Zn_{0.27}S_{1-x}Se_x$ films was 0 and 0.8 in solution**.** The temperature of substrate was controlled by an Iron-Constantan thermocouple. The films were deposited onto glass substrates (1x11x26mm^3) kept at a temperature of 275°C. The spray rate employed was 2.6ml/min and kept constant throughout the experiment. Nitrogen was used as carrier

gas. After deposition, the films were allowed to cool at room temperature. The spray pyrolysis deposition system was described in detail elsewhere (Caglar and Zor, 2003; Ilican et al., 2005). The film thickness was estimated by weighing method.

The electrical properties of these films have been investigated in the form of planar gold-semiconductor-gold structures. Gold electrodes have been deposited by using Leybold Heraus 300 Univex system.

Electrical measurements have been carried out in dark, in vacuum of $3x10^{-3}$mbar in the range between 10-320K using Oxford Cryostat 43305 and Hewlett Packard 4140B pA meter/dc Voltage Source. Choromel/Gold-Iron (0.03%) thermocouple was used for temperature measurements. Details of the experimental system is reported in the previous work (Caglar and Zor, 2001; Ilican and Zor, 2001).

The films were found to be n-type as determined from a hot probe test.

3. RESULTS AND DISCUSSION

Current-voltage characteristics at different temperatures are shown in Figure 1 and Figure 2 for $Cd_{0.73}Zn_{0.27}S$ film and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film, respectively. The current varied exponentially with the voltage, as shown in these figures.

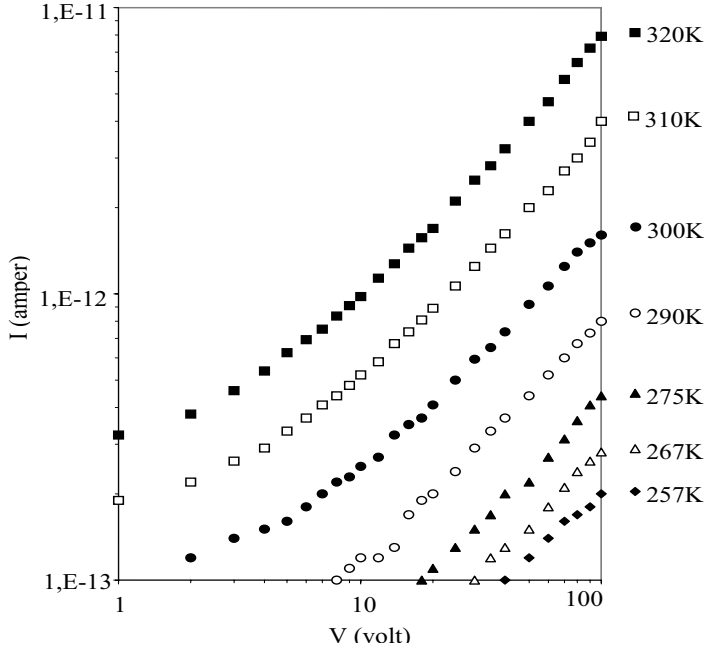

Figure 1. Current-Voltage characteristics for $Cd_{0.73}Zn_{0.27}S$ film.

The slope values corresponding to low and high voltage regions (0–10V and 10–100V) are given in Figure 1 and Figure 2. For these films, the low voltage region is non-ohmic at low temperature and ohmic at high temperature. For $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film the high voltage region is ohmic for high temperature, SCL for low temperature. It is determined that transition voltage is V_{tr}=10V for this film.

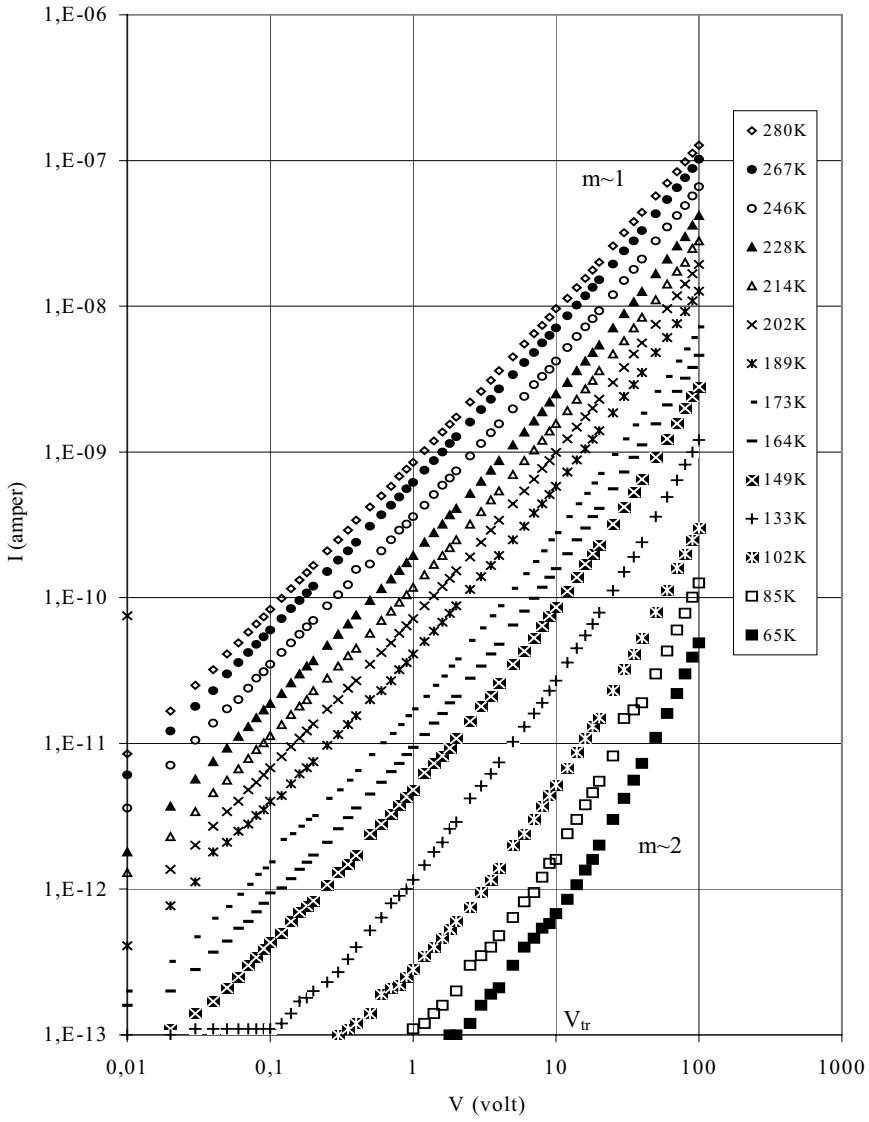

Figure 2. *Current-Voltage characteristics for $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film.*

The conductivity values of films calculated from Figure 1 and Figure 2 were given in Table1.

The plots of temperature-dependent conductivity of all films are shown in Figure 3 and Figure 4. It was seen that the conductivities of the films increased slowly at low temperatures and increased sharply at high temperatures. It can also be seen from these

Table 1. The conductivity values for $Cd_{0.73}Zn_{0.27}S$ and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ films at different temperatures.

Material	**T (K)**	**σ (Ωcm)$^{-1}$**
	257	2.07×10^{-12}
	267	3.31×10^{-12}
	275	4.96×10^{-12}
$Cd_{0.73}Zn_{0.27}S$	290	9.23×10^{-12}
	300	1.93×10^{-11}
	310	4.13×10^{-11}
	320	8.82×10^{-11}
	65	1.18×10^{-10}
	85	2.17×10^{-10}
	102	5.52×10^{-10}
	133	2.88×10^{-9}
	149	9.47×10^{-9}
	164	1.85×10^{-8}
$Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$	173	3.41×10^{-8}
	189	8.09×10^{-8}
	202	1.42×10^{-7}
	214	2.33×10^{-7}
	228	3.85×10^{-7}
	246	7.11×10^{-7}
	267	1.22×10^{-6}
	280	1.67×10^{-6}

figures that the conductivity of $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film are higher than the conductivity of $Cd_{0.73}Zn_{0.27}S$ film.

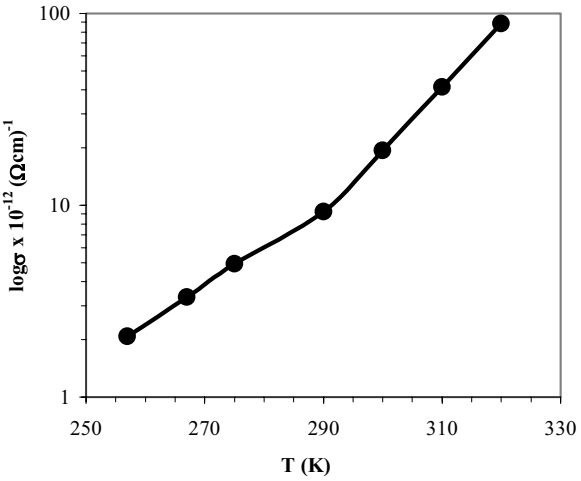

Figure 3. *The plot of temperature-dependent conductivity of $Cd_{0.73}Zn_{0.2}S$ film.*

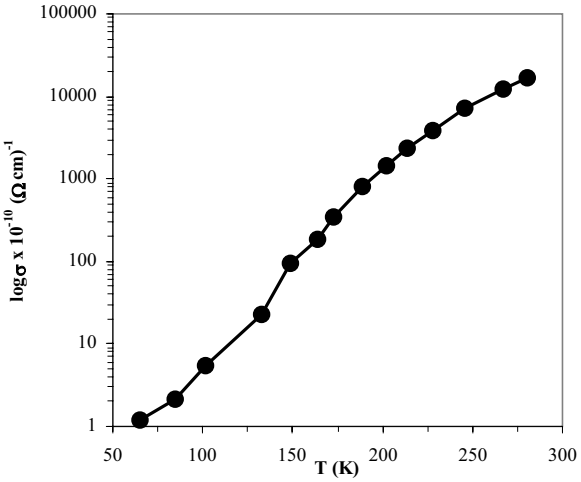

Figure 4. *The plot of temperature-dependent conductivity of $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film.*

Typical Arrhenius plots of $Cd_{0.73}Zn_{0.27}S$ and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ films are shown in Figure 5 and Figure 6. The current varied exponentially with the temperature, as shown these Figures. It is obvious from these figures that the conductivity plots show two activated regions in the temperature range studied. The activation energies in the different temperatures regions are given in Table 2.

Table 2. The activation energy values of $Cd_{0.73}Zn_{0.27}S$ and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ films.

Voltage (V)	$Cd_{0.73}Zn_{0.27}S$		$Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$	
	260-290K	290-320K	85-133K	133-320K
	ΔE (meV)		ΔE (meV)	
20	298	669	64	126
40	238	583	54	118
60	220	596	52	123
80	260	607	54	113
100	397	620	48	110

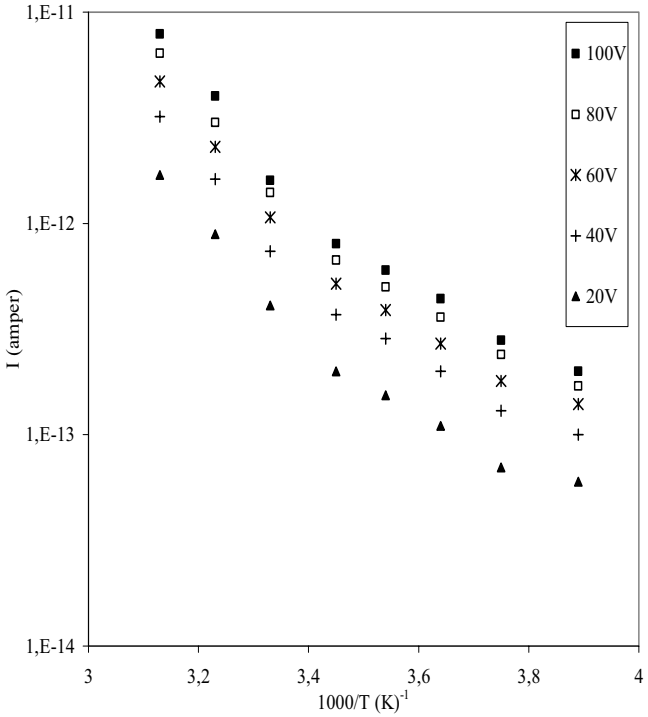

Figure 5. *Arrhenius plot for $Cd_{0.73}Zn_{0.27}S$ film.*

For $Cd_{0.73}Zn_{0.27}S$ film, the activation energy values obtained between 260-290K temperatures (220-397meV) were attributed to the ionization energy of the donor-like states. Namely, it was possible to determine that the donor-like states are located below the conduction band for $Cd_{0.73}Zn_{0.27}S$ film. Whereas, the activation energy values obtained between 290 and 320K temperatures (583-669meV) were to the donor-like traps.

For $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film, the activation energy values at low temperatures (48-64meV) corresponds to the hopping conduction involving the localized states induced by the structural and/or chemical disorder in the band gap. Whereas, the activation energy values obtained at higher temperatures (110-126meV) were to the donor-like traps.

4. CONCLUSION

$Cd_{0.73}Zn_{0.27}S$ and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ films have been deposited by the spray pyrolysis method at 275°C substrate temperature. Electrical properties of these films have been investigated in the form of planar gold-semiconductor-gold structures. These films were found to be n-type as determined from a hot probe test. For low temperatures in the range of low-applied voltages in both $Cd_{0.73}Zn_{0.27}S$ and $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ films the ohmic conduction is observed. For $Cd_{0.73}Zn_{0.27}S_{0.2}Se_{0.8}$ film the high voltage region is ohmic for high temperature, SCL for low temperature. The temperature dependence study of the current showed that in the high temperature range the impurity-band conduction mechanism dominates. In the low-temperature range the dominating conduction mechanism is the hopping of the carriers.

ACKNOWLEDGMENT

The authors are grateful to Prof. Dr. Muhsin ZOR from Anadolu University, Faculty of Science, Department of Physics for his technical and sciential help.

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