Metal Selenide semiconductor thin films: A Review

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Abstract: Recent research has emphasized on the preparation of metal chalcogenide thin films such as metal sulfide, metal selenide and metal telluride by using various deposition techniques. Because of these thin films possess very useful physical properties and could be found in many technical applications. In this review paper, study of the properties of metal selenide thin films will be reported.

Keyword: thin films, semiconductor, chemical bath deposition, selenide, electro deposition.

Introduction:

Selenium is located in Group 6 of the periodic table. It could be found in water, soil and some foods. Human need small amount of selenium due to its antioxidant properties, therefore protect cells from damage. Nowadays, the preparation of the metal selenide thin films has been explored by number of deposition techniques. Generally speaking, these deposition techniques are classed as either physical or chemical method. Usually, thin films prepared by chemical deposition methods are less expensive than those prepared by the capital intensive physical deposition technique.

Polycrystalline thin films have received a great deal of attention because of their potential application in the area of electronic and optoelectronic devices. Recent research has focused on the synthesis of metal chalcogenide thin films such as metal sulfide (SnS$_2$(1), MnS$_2$(2), MnS (3), CuS (4), Bi$_2$S$_3$(5), Ni$_3$S$_2$(6), Cu$_2$S (7),CdS (8), FeS (9), FeS$_2$(10), ZnS(11), NiS(12), PbS(13), Sb$_2$S$_3$(14), Ni$_3$Pb$_2$S$_3$(15), Cu$_3$SnS$_3$(16-18), SnS$_{0.5}$Se$_{0.5}$(19),Cu$_3$SnS$_4$(20)), metal selenide and metal telluride (CdTe(21), Sb$_2$Te$_3$(22),ZnTe(23), Bi$_2$Te$_3$(24), CdSe$_{0.6}$Te$_{0.4}$(25), Cd$_{1-x}$Zn$_x$Te(26), Zn$_{1-x}$HgxTe(27), GaCuTe$_2$(28), Ag$_2$ScTe (29) and GeSbTe (30)) using various methods. These materials are of practical interest because of very useful optical, mechanical and electrical properties. Here, in this review paper, an investigation of the properties of metal selenide thin films will be reported.

Literature survey:

In recent years, synthesis and characterization of semiconductor thin films are of great importance. There are many reports available on the growth of different types of thin films by various techniques as shown below.

Many scientists have reported that the use of Sb$_2$Se$_3$ thin films in solar cells(31,32). Several deposition techniques such as successive ionic layer adsorption and reaction(33), thermal evaporation(34), chemical bath deposition(35) and electro deposition method(36)have been developed to produce these compounds. Rodriguez-Lazcano et al (35) have reported that the films are photosensitive, with dark and photoconductivity values are 2X10$^8$ and 10$^6$ (Ωcm)$^{-1}$, respectively.
Cadmium selenide thin films have been prepared by various deposition methods such as chemical bath deposition(37), spray pyrolysis(38), vacuum evaporation(39), electro deposition (40) and thermal evaporation(41). Literature review reveals that the band gap and absorption coefficient value are 1.8 eV and $0.58 \times 10^5 \text{cm}^{-1}$, respectively. The conductivity of CdSe thin films is n-type(38,40), indicating that they can be utilized in solar cells, photo detection, light amplifiers and light emitting diodes applications.

Abundant literature is available on the preparation of tin selenide films such as chemical bath deposition(42), spray pyrolysis(43), reactive evaporation(44), thermal evaporation(45) and electro deposition method(46).Bindu and Nair (47) have reported that the band gap is in the range of 1 to 1.27 eV, while the electrical conductivity is 0.01-0.2 $\Omega^{-1}\text{cm}^{-1}$. Wahab et al (48) have reported that the absorption efficient was observed to be larger than $10^5 \text{cm}^{-1}$. On the other hand, the SnSe films were electrochemically deposited onto Au (111) substrates by Mustafa and Ilkay(46). They found that the stoichiometric SnSe films could be obtained at -0.5 V. Also, the films obtained are direct transition with band gap of 1.3 eV.

Zinc selenide thin films play important roles in optoelectronic devices. These films have been successfully prepared using chemical bath deposition(49), thermal evaporation(50), vacuum evaporation (51) and electrodeposition method(52). Several researchers have reported on the electro deposition of ZnSe films from aqueous solution on different substrates such as fluorine doped tin oxide(53), stainless steel, indium tin oxide (52) and zinc substrate. ZnSe thin films have a large value of band gap among the group II-VI compound. The band gap for these films was found to be 2.7 eV(54) with a direct transition.

Copper selenide films have a wide direct band gap in the range between 2.1-2.7 eV. As shown in literature reports, they are normally crystallized in hexagonal and orthorhombic (55) structure according to X-ray diffraction studies. Numerous methods have been employed to obtain these films such as chemical bath deposition(56), pulsed laser deposition(57), thermal evaporation(58) and electro deposition (59). Conductivity of $1 \times 10^8 \Omega^{-1}\text{cm}^{-1}$ and sheet resistance between 8-24$\Omega$ was obtained from experiment results indicating that CuSe films could be used in the solar cell production.

Nickel selenide thin films are important semiconducting materials and could be considered as one of the absorbent materials used in photoelectrochemical cell. They are direct transition semiconductors (60) and the band gap values obtained were estimated to be 2.11-2.52 eV. Hankare et al (61) have reported that the chemical bath deposited nickel selenide thin films revealed polycrystalline nature with hexagonal system. They also claimed that the band gap was 1.6 eV with p-type conduction. Meanwhile, Zainal et al (62) have found that the electro deposition in the presence of triethanolamine in aqueous solution was found to offer some improvement in the synthesis of NiSe films. Their photoelectrochemical analysis indicates outstanding photo activity for the films deposited at -0.7V.

As far as I know, over the last few decades, there have been a few research studies on the preparation of ternary [Table 1] and quaternary metal selenide [Table 2] thin films by using different deposition techniques. In future, extensive research should be carried out to grow various kinds of metal selenide thin films due to selenium is considered to be non-toxic substances. It is because of the obtained experiment findings not only broaden our knowledge on mesoscopic physics phenomena, but also on fundamental theories about the effect of its dimension, size and morphology.

### Table 1: Ternary metal selenide thin films

<table>
<thead>
<tr>
<th>Thin films</th>
<th>Technique</th>
<th>Reference</th>
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<tbody>
<tr>
<td>CdZnSe</td>
<td>Photoelectrochemical deposition</td>
<td>Ham et al, 2008(63)</td>
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<tr>
<td>CuInSe$_2$</td>
<td>Thermal evaporation</td>
<td>Nordin et al, 2014 (64)</td>
</tr>
<tr>
<td>CdSSe</td>
<td>Thermal evaporation</td>
<td>Kale et al, 2014 (65)</td>
</tr>
<tr>
<td>CdIn$_2$Se$_4$</td>
<td>Potentiostatic deposition</td>
<td>Balladores et al, 2014 (66)</td>
</tr>
<tr>
<td>CuGaSe$_2$</td>
<td>Aerosol Assisted Chemical Vapour deposition</td>
<td>Mahboob et al, 2014 (67)</td>
</tr>
</tbody>
</table>
### Table 2: Quaternary metal selenide thin films

<table>
<thead>
<tr>
<th>Thin films</th>
<th>Technique</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuIn0.7Ga0.3Se2</td>
<td>Aerosol Assisted Chemical Vapour deposition</td>
<td>Mahboob et al, 2014 (67)</td>
</tr>
<tr>
<td>CuIn(S,Se)2</td>
<td>Spin coating</td>
<td>Arnou et al, 2015 (68)</td>
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<tr>
<td>Cu2ZnSnSe4</td>
<td>Electro deposition</td>
<td>Jeon et al, 2014 (69)</td>
</tr>
<tr>
<td>CuZnSnSe</td>
<td>Vacuum evaporation</td>
<td>Sabli et al, 2013 (70)</td>
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### Conclusion:

In this review paper, as well known, various deposition techniques have been used in preparing metal selenide thin films. The obtained research findings indicating that these films have potential application in solar cell, electronic and optoelectronic devices.

### Reference

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