# Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 9 (3): 593-596, 2009
ISSN 1812-5654


# Ingot Fabrication of Base Material for Solar Cell $CuInSe_2$

A.H. Soepardjo
Department of Physics, Faculty of Mathematics and Natural Sciences,
University of Indonesia, F Building, 2nd Floor, Depok 16424, Indonesia

**Abstract:** Research on base material fabrication for solar cell was done using the vertical Bridgman furnace method and the final products are ingots of $CuInSe_2$. The ingots were then characterized by using optical and electrical characterization methods. Optical characterization includes measuring with X-ray Diffraction (XRD) to determine the parameter value of lattice crystal and using Energy Dispersive Spectroscopy (EDS) to determine the material composition. Extension coefficient, dielectric constant and refraction index were also measured by using elipsometer. Electric characterization was used to classify the type of the material using galvanometer.

**Key words:** Bridgman method, chalcopyrite, stochiometric, ingot

## INTRODUCTION

The I-III-$V_2$ material, is the base material for making solar cell that have high coefficient for absorption (Irmansyah *et al*., 2002; Wahyuniati and Soepardjo, 2002; Soepardjo and Syah, 1996; Harsono *et al*., 1994; Noufi and Dick, 1985). In the future, it is hoped this the material could replace the current base material such as silicon. The fabrication of I-III-$VI_2$ has already been successfully conducted by Chu *et al*. (1992), Rincón (1987) and Belevich *et al*. (1986) using the vertical Bridgman furnace method. This research is focused on material fabrication in polycrystalline form, since the time it takes to complete the process is about three days, relatively short process time. Neumann and Tomlinson (1990) have made a monocrystalline form of the materials but the process took a long time around 3 weeks and it was done using accurate temperature controller equipment. The material has a basic structure of tetrahedric and it's also known as chalcopyrite structure from the diamond family, it can be shown in Fig. 1. The value of the lattice crystal parameter is a = b, c/a ≈ 2 and it has a boiling point of 986°C (Fearheiley, 1986; Bachmann *et al*., 1984) with a band gap of 1 to 1.7 eV .

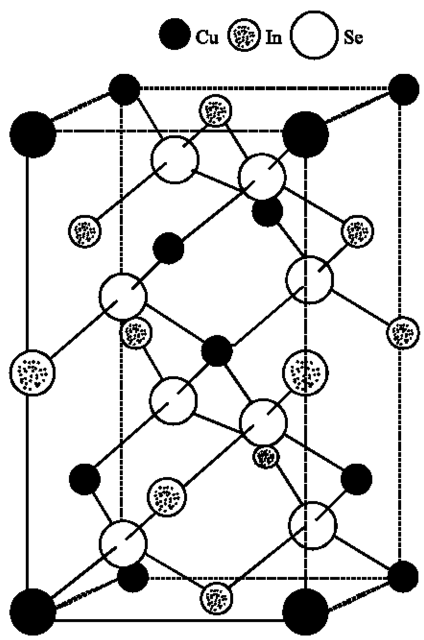

Fig. 1: Material structure of chalcopyrite

The solar cell fabrication process by Bridgman method is the first process to produce a solar cell device, the second process is the making of thin film from the materials by means of evaporation. The process of making thin film and its characterization are not explained in this study.

## MATERIALS AND METHODS

The equipment used in the fabrication process is a vertical Bridgman furnace which is shown in Fig. 2. The ingot preparation of material can explain as bellow; each of the material element Cu, In and Se has a purity of 6 N, they are then weighed by stochiometric composition. Then the materials are inserted to quartz tube, in which the tube's end are sharpen. It is then vacuumed with a pressure of $10^{-3}$ Torr. The tube was then closed and welded shut. Before the insertion of materials, the tube was washed with distilled water and 10% HF acid solution. The tube was then dried by heating it inside the

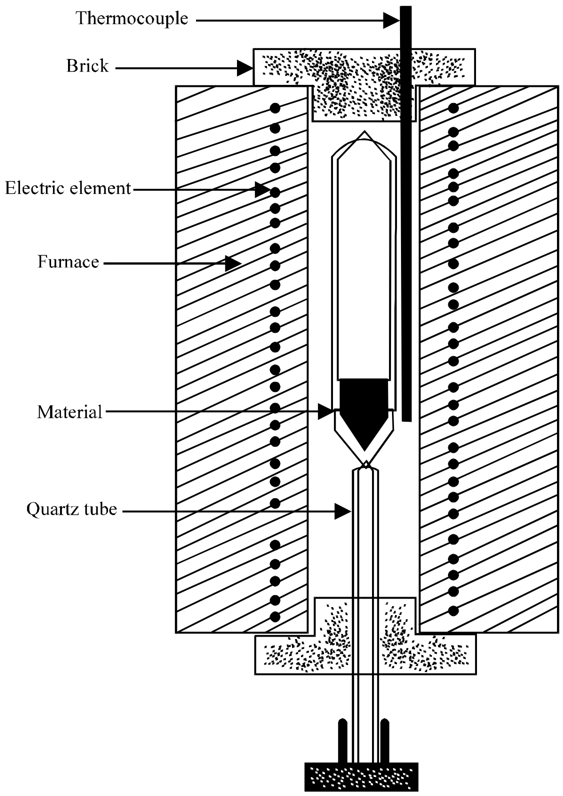


Fig. 2: Vertical Bridgman furnace

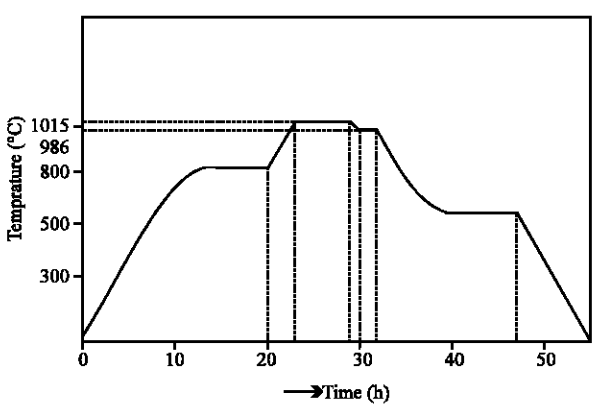


Fig. 3: Heating and cooling process of $CuInSe_2$

furnace cabinet at 300°C for 6 h. After the tube and the materials inside are welded shut, the next step of the process is treating them inside the Bridgman furnace.

The heating and cooling process can follow like this; the heating process started low speed with increase the temperature up to 800°C during 10 h. After this step the temperature keep constant during 10 h and continue to increase temperature up to 1000°C during 3 h. With this

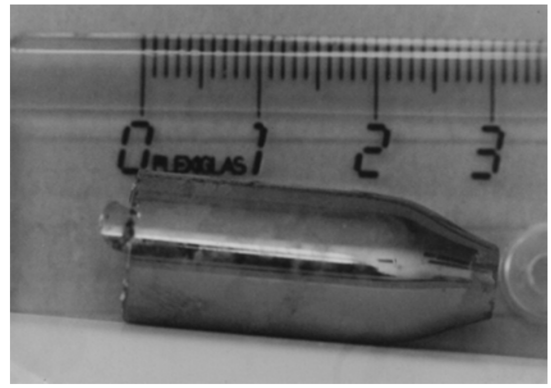

Fig. 4: Polycrystalline ingot viewed from the side

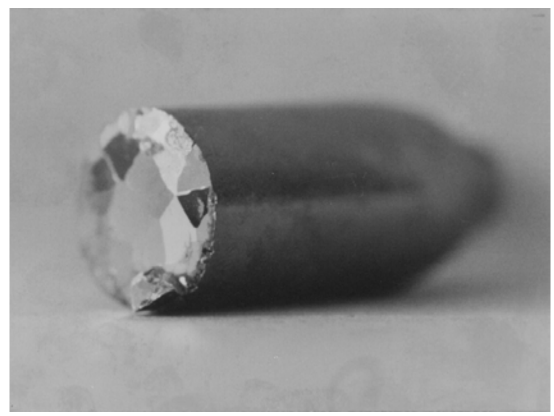

Fig. 5: Cross section of polycrystalline ingot

temperature keep constant and process rocking during 5 h. The next step is cooling process, started to decrease temperature during 2 h up to boiling temperature that is 986°C. During 2½ h this temperature keep constant and finally the last process is decrease the temperature with low speed up to room temperature. The overall heating and cooling process can be followed in Fig. 3. The whole process takes about 3 days to complete.

## RESULTS AND DISCUSSION

After the heating and cooling processes which took about 3 days, the resulting ingot was extracted from the tube by breaking the end of the tube. The ingot was then measured, the average length is about 3 cm with a diameter of 13 mm. The result of ingot samples can be viewed in Fig. 4 and 5.

From these Fig. 4 and 5, visually the ingot shape is solid without pores, this indicated that quality of material product is very good result.

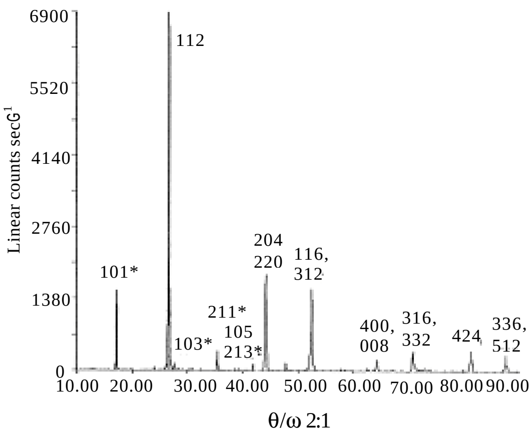


Fig. 6: The typical XRD diagram of $CuInSe_2$ powder

Table 1: The lattice parameter for several ingots

| Samples | a (Å) | c (Å) | c/a |
|---|---|---|---|
| 1 | 5.7761 | 11.5810 | 2.005 |
| 2 | 5.7737 | 11.5813 | 2.006 |
| 3 | 5.7822 | 11.5858 | 2.004 |
| 4 | 5.7877 | 11.5805 | 2.001 |
| 5 | 5.7974 | 11.5656 | 1.995 |
| 6 | 5.8163 | 11.5497 | 1.986 |

**Optical characterization:** Optical characterization for this experiment is characterization using X-ray Diffraction (XRD) to determine the peak orientation of the Miller index, then the lattice crystal parameter a, c and c/a were calculated. Table 1 shows calculation result the lattice parameters a, c and c/a for 6 ingots.

The lattice parameter crystal values a, c and c/a shows that the material structure products were a form of chalchopyrite with c/a ≈ 2.

**X-ray diffraction measurement (XRD):** X-ray diffraction measurement was done using a type MZ IV Diffractometer. The resulting ingot was cut into several pieces and each piece was grained to a powder which then are mounted on glass substrate. Result from XRD shows Debye-Scherer diffraction peaks as a function of a deviation angle of $2\theta$.

Figure 6 shows that the crystal orientation peaks of [101], [112], [204, 220], [116, 312], [316, 332] and [336, 512], it shows very bold and sharp peaks, that is the principal peaks on the material $CuInSe_2$ (Pern *et al*., 1991; Yamaguchi *et al*., 1992).

**EDS measurements:** The material composition was analyzed using Energy Dispersive Spectroscopy. The equipment used for EDS measurement is an Energy Dispersive Spectroscopy produced by Cambridge type S 360. The result of the measurements

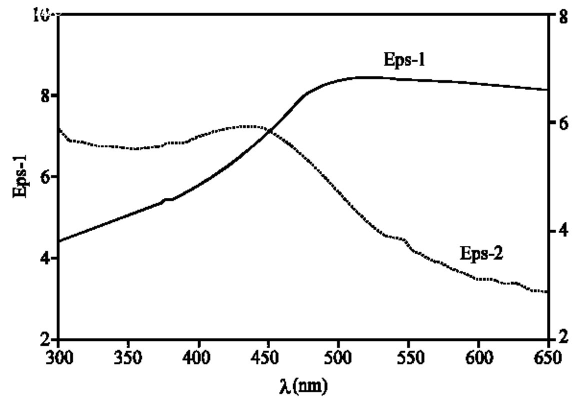


Fig. 7: Dielectric constant as a function of wavelength

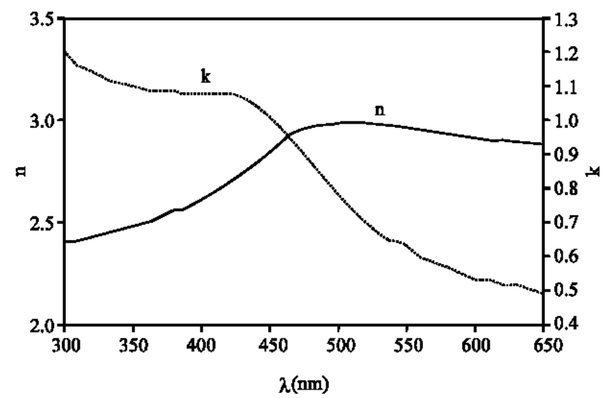


Fig. 8: Refraction index n, k as a function of wavelength

Table 2: Composition of materials

| Samples | Cu (%) | In (%) | Se (%) | Type |
|---|---|---|---|---|
| 1 | 18.3 | 27.4 | 54.3 | p |
| 2 | 16.9 | 30.0 | 53.1 | p |
| 3 | 22.9 | 26.9 | 50.2 | n/p |
| 4 | 23.5 | 26.2 | 50.3 | p |
| 5 | 24.6 | 25.8 | 49.6 | p |
| 6 | 23.4 | 24.9 | 51.7 | p |

using this equipment is shown in Table 2. The measurement using EDS shows that the best material compose of Cu = 24.6%; In = 25.8% and Se = 49.6%, is close to stochiometric.

**n, k and ϵ measurement:** The measurement of refraction index (n), extension coefficient (k) and dielectric constant (ϵ) was done using an elipsometer from a wavelength of 300-600 nm.

From Fig. 7 and 8 the values of refraction index, extension coefficient and dielectric constant measurement for the product of $CuInSe_2$ material shows that the material produced is indeed $CuInSe_2$ (Kazmerski *et al*., 1983).

**Electrical characterization**

**Type measurement:** Electrical characterization in this research only measuring the type of material using galvanometer. The result of the measurement of the $CuInSe_2$ material can be seen in Table 2, the type of ingots are type p, except for sample 3 (Migliorato *et al*., 1975; Rockett *et al*., 1991).

## CONCLUSION

Fabrication of base material for solar cell on $CuInSe_2$ in this research is relatively easy by using Bridgmann furnace. The characterization of material shows that parameters physics of material such as; lattice crystal a, c and values c/a, structure crystal, peaks of material at XRD, atomic composition of material, index refraction and type of material, are relatively good results. For the future development of solar cell this research it is basically to produce device solar cell.

## ACKNOWLEDGMENT

I would like to thank to Professor F. Guastavino for his advisement in this research and also for his laboratory in Centre d'Electronique de Montpellier (CEM), Universite de Montpellier II, France.

## REFERENCES

Bachmann, K.J., M. Fearheiley, Y.H. Shing and N. Tran, 1984. Phase relations in the Cu, In, Se system and the properties of $CuInSe_2$ single crystals. Applied Phys. Lett., 44: 407-409.

Belevich, N.N., A.I. Lukomskii, L.A. Makovetskaya and A.P. Chernyakova, 1986. Absorption edge of stoichiometric and nonstoichiometric $CuInSe_2$ crystals. Phys. Stat. Sol., 133: K49-K52.

Chu, J.W., A.J. Donohoo and D. Haneman, 1992. Properties of $CuIn_{1-x}Ga_xSe_2$ Solar Energy Mater. Solar Cells, 25: 87-92.

Fearheiley, M.L., 1986. The phase relations in the Cu, In, Se system and the growth of $CuInSe_2$ single crystals. Solar Cells, 16: 91-100.

Harsono, S., M. Lachab, A. Attia, F. Guastavino and C. Llinares, 1994. Effect of annealing in a selenium atmosphere on the properties of flash evaporated $CuInSe_2$ polycrystalline thin films. Solid State Phenomena, 37-38: 515-520.

Irmansyah, A.H. Soepardjo and A. Rezavidi, 2002. $CuGaSe_2$ polycrystal fabrication and its lattice constant calculation. J. Kontribusi Fisika Indonesia, 13: 27-27.

Kazmerski, L.L., M. Hallerdt, P.J. Ireland, R.A. Mickelsen and W.S. Chen, 1983. Optical properties and grain boundary effects in $CuInSe_2$. J. Vac. Sci. Technol. A, 1: 395-395.

Migliorato, P., J.L. Shay and H.M. Kasper, 1975. Electrical properties and luminescence of $CuInSe_2$. J. Elect. Mater., 4: 209-222.

Neumann, H. and R.D. Tomlinson, 1990. Relation between electrical properties and composition in $CuInSe_2$ single crystals. Solar Cells, 28: 301-301.

Noufi, R. and J. Dick, 1985. Compositional and electrical analysis of the multilayers of a $CDs/CuInSe_2$ solar cell. J. Applied Phys., 58: 3884-3887.

Pern, F.J., R. Noufi, A. Mason and A. Franz, 1991. Characterizations of electrodeposited $CuInSe_2$ thin films: Structure, deposition and formation mechanisms. Thin Solid Films, 202: 299-314.

Rincón, C., 1987. A model for the band gap shrinkage in the chalcopyrite semiconductor $CuInSe_2$. Solid State Commun., 64: 15-17.

Rockett, A. and R.W. Birkmire, 1991. $CuInSe_2$ for photovoltaic applications. J. Applied Phys., 70: 81-97.

Soepardjo, A.H. and A.H.N. Syah, 1996. $CuInSe_2$ crystal growth by Bridgman vertical furnace. Proceeding National Seminar On Applied Physics and Environmental, June 25-26, Bandung, Indonesia, pp: 221-231.

Wahyuniati, E. and A.H. Soepardjo, 2002. $AgInSe_2$ polycrystalline growth by Bridgman vertical furnace and its characterization. J. Fis. HFI, A5: 1-5.

Yamaguchi, T., J. Matsufusa and A. Yoshida, 1992. Thin films of $CuInSe_2$ prepared by RF sputtering from various compositional powder targets. Solar Energy Mater. Solar Cells, 27: 25-35.