

## Information on Doctoral thesis of Fellows Ngo Dinh Sang

1. Full name: NGO DINH SANG
2. Sex: Male
3. Date of birth: 01/10/1976
4. Place of birth: Vinh Phuc
5. Admission decision number: 5429/QĐ-SĐH. Dated 30/10/2008 by President of Vietnam National University, Hanoi
6. Changes in academic process:  
  
Decision No.527/QĐ-SDH on changing doctoral thesis supervisor, February 14th, 2011.  
  
Decision No.2165/QĐ-SDH on adding doctoral thesis supervisor, June 1st, 2012
7. Official thesis title: Simulation of device physics, synthesis and study properties of some main layers of the solar cell based on CIGS thin films.
8. Major: Solid State Physics
9. Code: 62 44 07 01
10. Supervisors: 1) Assoc. Prof. Dr. Pham Hong Quang

2) Dr. Le Tuan Tu

### 11. Summary of the new findings of the thesis

+ The effects of some important parameters have been studied by simulation. The results point out the optimal values of 3000 nm for CIGS layer thickness and of 1.4 eV for band gap. The device based on these baselines exhibits the performances as following: the short current  $J_{sc} = 30.19 \text{ mA/cm}^2$ ; the open-circuit voltage  $V_{oc} = 0.67 \text{ V}$ ; fill factor  $FF = 0.83$  and conversion efficiency  $\eta = 17,6 \%$ .

+ Good quality transparent conducting Al-doped ZnO films were deposited on quartz substrates using pulsed electron deposition (PED). Two series of films were made, one deposited at room temperature but at four pressures, viz., 5, 10, 15 and 20 mTorr of oxygen and one deposited at 10 mTorr oxygen pressure but at the substrate temperature ranged from room temperature to 600 °C. For the first series films, the optimal oxygen pressure of 10 mTorr was found. For the second series films, the lowest resistivity of  $3.4 \times 10^{-2} \Omega \cdot \text{cm}$  was obtained in the film grown at 400 °C.

+  $\text{Cu}(\text{InGa})\text{Se}_2$  films were grown by PED from a commercial  $\text{Cu}(\text{In}_{0.7}\text{Ga}_{0.3})\text{Se}_2$  target. The properties of the films such as morphology, thickness, crystallinity, and absorption were found to depend strongly on the deposition conditions. The best film was obtained at the discharge voltage of 12 kV and at substrate temperature of 600

°C. The obtained results are remarkable in demonstration of the ability of the PED to produce CIGS absorber layer for high performance photo-voltaic cells.

+ To find the most suitable complexing agent for Ga deposition, CuGaSe<sub>2</sub> (CGS) thin films were deposited on ITO substrates by electrodeposition from the solutions with different acidic agents. The concentration of Ga has reached to the value of about 16% at. at potential of -0.95 V from the solutions with hydrochloric and sulphamic acids.

+ CuInGaSe (CIGS) thin films were deposited on Mo/soda-lime glass substrates by electrodeposition at different potentials ranging from -0.3 to -1.1 V vs. Ag/AgCl. The variation in composition with applied potentials was explained by CV data. A suitable potential range from -0.8 V to -1.0 V was found for obtaining films with desired and stable stoichiometry. By adjusting the composition of electrolyte, we achieved the desired Cu(In<sub>0.7</sub>Ga<sub>0.3</sub>)Se<sub>2</sub> stoichiometry.

+ In order to examine the application potential of CIGS layer deposited by electrodeposition, the simple photovoltaic cells have been made and the conversion efficiency of 12.6% has been obtained for the best sample.

12. Practical applicability, if any: For application in renewable energy.

13. Further research directions, if any: Based on the obtained results, we plan to synthesise the CIGS thin film solar cell with a complete configuration.

14. Thesis-related publications:

Pham Hong Quang, Ngo Dinh Sang, Tran Manh Ha, Le Tuan Tu, Nguyen Thi Thu, Pham Hong Hue. (2009), "Simulation on operation of a CuIn<sub>1-x</sub>Ga<sub>x</sub>Se<sub>2</sub> thin films solar cells", *Proceedings of the 6<sup>th</sup> Conference on Solid state Physics and Materials Science*, pp. 454-457.

Pham Hong Quang, Ngo Dinh Sang, Do Quang Ngoc. (2011), "Synthesis of thin films by PED", *Proceedings of the 7<sup>th</sup> Conference on Solid state Physics and Materials Science*, pp. 241-246.

Ngo Dinh Sang, Pham Hong Quang, Le Tuan Tu. (2011), "Electrodeposition of CuGaSe<sub>2</sub> layer from solutions with different complexing agents", *Communications in Physics* 21 (4), pp. 365-372.

Ngo Dinh Sang, Pham Hong Quang, Le Tuan Tu, Dang Thi Bich Hop. (2012), "Effect of electrodeposition potential on the composition and morphology of CIGS absorber thin film", *Bulletin of Materials Science*, accepted.

Ngo Dinh Sang, Pham Hong Quang, Do Quang Ngoc. (2012), "Effect of oxygen pressure on the charge transport property of Al-doped ZnO films grown by pulsed electron deposition", *Communications in Physics* 22 (2), pp. 155-160.

Ngo Dinh Sang, Pham Hong Quang, Do Quang Ngoc. (2012), "Pulsed Electron Deposition (PED) – A novel tool for growth of thin films", *Communications in Physics* 22 (1), pp. 65-73.

Pham Hong Quang, Ngo Dinh Sang, Do Quang Ngoc. (2012), "Pulsed electron beam deposition of transparent conducting Al-doped ZnO films", *Thin Solid Films* 520, pp. 6455-6458.