การเคลือบด้วยลำโมเลกุลและการหาลักษณะเฉพาะของชั้นคอปเปอร์อินเดียมแกลเลียมไดซีลีไนด์ที่มีช่องว่างแถบพลังงานกว้างสำหรับเซลล์แสงอาทิตย์ชนิดฟิล์มบาง

นางสาวปณิตา ชินเวชกิจวานิชย์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาฟิสิกส์ ภาควิชาฟิสิกส์
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2549

ISBN 974-14-2988-6

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

MOLECULAR BEAM DEPOSITION AND CHARACTERIZATION OF WIDE-BAND-GAP $Cu(In,Ga)Se_2$ FOR THIN FILM SOLAR CELLS

Miss. Panita Chinvetkitvanich

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Physics
Department of Physics
Faculty of Science
Chulalongkorn University
Academic Year 2006

ISBN 974-14-2988-6

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492239

Thesis Title	MOLECULAR BEAM DEPOSITION AND CHARACTERIZATION OF WIDE-BAND-GAP $Cu(In,Ga)Se_2$ FOR THIN FILM SOLAR CELLS
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Field of Study	Physics
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ปณิตา ชินเวชกิจวานิชย์ : การเคลือบด้วยลำโมเลกุลและการหาลักษณะเฉพาะของชั้นคอปเปอร์อินเดียมแกลเลียมไดซีลีไนด์ที่มีช่องว่างแถบพลังงานกว้างสำหรับเซลล์แสงอาทิตย์ชนิดฟิล์มบาง. (MOLECULAR BEAM DEPOSITION AND CHARACTERIZATION OF WIDE-BAND-GAP Cu(In,Ga)Se_2 FOR THIN FILM SOLAR CELLS) อ. ที่ปรึกษา : ผศ. ดร. ขจรยศ อยู่ดี, อ. ที่ปรึกษาร่วม : ผศ. สมพงศ์ ฉัตราภรณ์, 162 หน้า. ISBN 974-14-2988-6

ได้เตรียมฟิล์มบางพหุผลึก $CuIn_{1-x}Ga_xSe_2$ (Cu(In,Ga)Se_2) โดยวิธีการเคลือบด้วยลำโมเลกุล (MBD) ร่วมกับการใช้เทคนิคการตรวจวัดสัญญาณ ณ เวลาจริง เพื่อใช้ควบคุมกระบวนการและชี้จุดสิ้นสุด (EPD) ในการทดลองเตรียมฟิล์มบาง Cu(In,Ga)Se_2 ได้ใช้โปร์ไฟล์อุณหภูมิ 2 แบบ โดยแบบแรกคือ two-stage process เริ่มต้นจาก Cu-rich stage ด้วยการปลูกให้ฟิล์มมีสัดส่วนอะตอมของ [Cu]/([In]+[Ga]) มากกว่าหนึ่ง (y>1) แล้วต่อด้วย Cu-poor stage จนกระทั่งได้เนื้อฟิล์มทั้งหมดที่มีค่า y<1 และหยุดปลูกที่ค่า y≈0.9 ทั้งนี้ได้เตรียมฟิล์มบาง $CuIn_{1-x}Ga_xSe_2$ ที่แปรค่า x ตั้งแต่ 0 ถึง 1 และได้เตรียมฟิล์มบาง $CuGaSe_2$ ที่แปรค่า y จาก 1.45 ถึง 0.7 จากผลการวิเคราะห์ฟิล์มด้วยวิธี XRD และ SEM พบว่าฟิล์มที่เตรียมด้วยวิธี MBD แบบนี้มีโครงสร้างแบบซาลโคไพไรท์ โดยโครงผลึกหันระนาบ (112) ขนานกับระนาบของแผ่นรองรับเป็นจำนวนมาก มีเกรนเป็นแท่งใหญ่และผิวขรุขระมีรอยแตกแยกลึก จากผลการวัดลักษณะเฉพาะของกระแสและความต่างศักย์ไฟฟ้า (I-V) พบว่าเซลล์แสงอาทิตย์ของฟิล์ม $CuIn_{1-x}Ga_xSe_2$ ที่เตรียมแบบ two-stage process นี้มีประสิทธิภาพสูงถึง 11% (ที่ค่า x=0.3) และประสิทธิภาพของเซลล์มีค่าลดลงเมื่อ $x \geq 0.5$ ส่วนโปร์ไฟล์แบบที่สอง three-stage process เริ่มต้นปลูกชั้น $(In,Ga)_2Se_3$ precursor มีค่า y=0 แล้วต่อด้วย Cu-rich stage จนกระทั่งได้เนื้อฟิล์มมีค่า y>1 แล้วต่อด้วย Cu-poor stage จนกระทั่งได้เนื้อฟิล์มที่มีค่า y≈0.9 จากผลการวิเคราะห์ด้วยวิธี XRD และ SEM พบว่าฟิล์มที่เตรียมด้วยวิธี MBD แบบนี้มีโครงสร้างแบบซาลโคไพไรท์ โครงผลึกหันระนาบ (112) ขนานกับระนาบของแผ่นรองรับเป็นจำนวนน้อยกว่าแบบแรก มีเกรนเป็นแท่งและผิวเรียบมีรอยแตกแยกที่ไม่ลึก ทั้งนี้พบว่ามี recrystallization จากชั้นอสัญฐาน $(In,Ga)_2Se_3$ precursor ไปเป็นพหุผลึก Cu(In,Ga)Se_2 ที่มีโครงสร้างแบบซาลโคไพไรท์ ซึ่งคาดว่าเป็นจุดเริ่มต้นของเฟสซาลโคไพไรท์ที่เสถียร สำหรับเซลล์แสงอาทิตย์ของฟิล์ม Cu(In,Ga)Se_2 ที่เตรียมแบบ three-stage process นี้ได้ค่าประสิทธิภาพที่สูงถึง 15.3% (ที่ค่า x=0.3) อีกทั้งจากผลการวิเคราะห์เชิงแสงของฟิล์ม $CuGaSe_2$ ที่แปรค่า y จาก 1.45 ถึง 0.7 ซึ่งเตรียมด้วยวิธี MBD นี้ ยังพบว่ามีคุณภาพสูงในระดับ excitonic grade อีกด้วย

ภาควิชา ฟิสิกส์ ลายมือชื่อนิสิต.....

สาขาวิชา ฟิสิกส์ ลายมือชื่ออาจารย์ที่ปรึกษา.....

ปีการศึกษา 2549 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

4473862123 : MAJOR PHYSICS
KEY WORD: SOLAR CELL / FABRICATION / IN SITU MONITORING / WIDE-BAND-GAP/ $CuIn_{1-x}Ga_xSe_2$

PANITA CHINVETKITVANICH: MOLECULAR BEAM DEPOSITION AND CHARACTERIZATION OF WIDE-BAND-GAP $Cu(In,Ga)Se_2$ FOR THIN FILM SOLAR CELLS. THESIS ADVISOR: ASST. PROF. KAJORNYOD YOODEE, PH.D., THESIS COADVISOR: ASST. PROF. SOMPHONG CHATRAPHORN. 162 pp. ISBN 974-14-2988-6

$CuIn_{1-x}Ga_xSe_2$: $Cu(In,Ga)Se_2$ polycrystalline thin films were prepared by the molecular beam deposition (MBD) method. The *in situ* monitoring technique was employed for process control and end-point detection (EPD). Two temperature profiles were performed in the $Cu(In,Ga)Se_2$ deposition process. First, the two-stage growth process was started with the Cu-rich stage such that the atomic ratio y=[Cu]/([In]+[Ga]) was greater than 1.0 ($y>1$), then followed by the Cu-poor stage until $y<1$ was reached, and the process was finished at $y\approx0.9$. Using this technique, the $CuIn_{1-x}Ga_xSe_2$ thin films of varied x from 0 to 1 and the $CuGaSe_2$ films of varied y from 1.45 to 0.7 were fabricated. The XRD and SEM results showed that all MBD polycrystalline $CuGaSe_2$ films were strongly (112) oriented chalcopyrite with large columnar grains and rough surfaces with deep crevices. From the current-voltage (I-V) measurement, the $Cu(In,Ga)Se_2$ thin film solar cells fabricated with two-stage growth process yielded efficiencies 11% ($x=0.3$) and the efficiencies decrease for wide band gap $Cu(In,Ga)Se_2$ ($x\geq0.5$) film. The second profile, three-stage growth process, started with $(In,Ga)_2Se_3$ precursor, $y=0$, followed by the Cu-rich stage until $y>1$, then finished with the Cu-poor stage at $y\approx0.9$. The XRD and SEM results of the grown films using this process showed weakly (112) oriented chalcopyrite with columnar grains and smooth surfaces with shallow crevices. The evidence of recrystallization from amorphous-$(In,Ga)_2Se_3$ precursor to polycrystalline $Cu(In,Ga)Se_2$ chalcopyrite structure was also observed and expected to be the origin of the stabilized $Cu(In,Ga)Se_2$ chalcopyrite phase. The $Cu(In,Ga)Se_2$ thin film solar cells fabricated using the three-stage growth process showed the efficiency up to 15.3% ($x=0.3$). The cell performances of the wide band gap $Cu(In,Ga)Se_2$ solar cells also improved using the three-stage growth process. Moreover, the optical characterization of $CuGaSe_2$ thin films revealed that the high quality with excitonic grade $CuGaSe_2$ polycrystalline thin films in a wide range of y from 1.45 to 0.70 could be fabricated by MBD method.

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Field of Study	Physics	Advisor's Signature Kajornyod Yoodee
Academic Year	2006	Co-advisor's Signature Somphong Chatraphorn

Acknowledgements

I would like to express my sincere gratitude and appreciation to my thesis advisors, Assistant Professor Dr. Kajornyod Yoodee and Assistant Professor Somphong Chatraphorn for their supervision, invaluable discussion, scientific skill, kindness suggestion and advice throughout the course of this thesis.

I would like to grateful to Assistant Professor Dr. Pisistha Ratanavararak, Assistant Professor Dr. Rattachat Mongkolnavin, Dr. Chatchai Srinitiwarawong and Associate Professor Dr. Pichet Limsuwan for serving as a chairman and committee, respectively. All of whom have made valuable comments and have been helpful in the production of this thesis.

I especially would like to thank to Dr. Chanwit Chityuttakan for many helpful discussions, new and interesting ideas, scientific knowledge, technical supports, and encouragement throughout the period of my graduate studies. I also would like to thanks Assistant Professor Dr. Sojiphong Chatraphorn for technical supports, especially AFM characterization, and thank to Mr. Rachsak Sakdanupab for his help in solar cell fabrication process.

Many thanks to my colleagues in Semiconductor Physics Research Laboratory, Department of Physics, Chulalongkorn University, for their friendship and help me in various way.

I would like to acknowledge the financial support from the Department of Physics, King Mongkutt's University of Technology Thonburi for the scholarship for my study. I also would like to acknowledge the assistantship granted by the National Research Council.

Finally, a deep gratitude is acknowledged to my family, for understanding, encouragement throughout the entire study and everything they have done for me.

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