

ห้องสมุดงานวิจัย สำนักงานคณะกรรมการการวิจัยแห่งชาติ



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CHARACTERIZATION OF NANOSTRUCTURED METAL SULFIDES  
SYNTHESIZED USING SOLVOTHERMAL METHOD

CHALERMOCHAI PILAPONG

DOCTOR OF PHILOSOPHY  
IN CHEMISTRY

THE GRADUATE SCHOOL  
CHIANG MAI UNIVERSITY  
JANUARY 2012

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**CHALERMCHAI PILAPONG**

**A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN  
PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY  
IN CHEMISTRY**

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6 January 2012

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Chalermchai Pilapong

|                                  |   |            |
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## ABSTRACT

**E46224**

Some nanostructured metal sulfides (CdS, Bi<sub>2</sub>S<sub>3</sub> and CuS) were synthesized by solvothermal method. Then they were characterized by various techniques, such as XRD, SEM, TEM, HRTEM, SAED, FTIR, Raman, UV-NIR and PL to determine their phases, morphologies, growth directions, lattice vibrations and optical properties, controlled by types and amount of starting materials, lengths of reaction time and temperatures. In this research, formation mechanisms of the metal sulfides with different morphologies were proposed according to the experimental results, including the benefits of Bi<sub>2</sub>S<sub>3</sub> and CuS for dye sensitized solar cells (DSSCs).



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การหาลักษณะเฉพาะของโลหะซัลไฟด์โครงสร้างนาโน  
ที่สังเคราะห์โดยวิธีโซลโวเทอร์มอล

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บทคัดย่อ

**E 46224**

ได้สังเคราะห์โลหะซัลไฟด์โครงสร้างนาโนบางชนิด (แคดเมียมซัลไฟด์ (CdS) บิสมัทซัลไฟด์ ( $\text{Bi}_2\text{S}_3$ ) และคอปเปอร์ซัลไฟด์ ( $\text{CuS}$ )) โดยวิธีโซลโวเทอร์มอล จากนั้นหาลักษณะเฉพาะของโลหะซัลไฟด์ดังกล่าวด้วยเทคนิคต่าง ๆ เช่น การเลี้ยวเบนของรังสีเอกซ์ (XRD) จุลทรรศน์อิเล็กตรอนแบบส่องกราด (SEM) จุลทรรศน์อิเล็กตรอนแบบส่องผ่าน (TEM) จุลทรรศน์อิเล็กตรอนแบบส่องผ่านชนิดมีความละเอียดสูง (HRTEM) การเลี้ยวเบนของอิเล็กตรอนแบบเลือกพื้นที่ (SAED) สเปกโทรสโกปีของอินฟราเรด (FTIR) สเปกโทรสโกปีของรามาน (Raman) สเปกโทรสโกปีของอัลตราไวโอเลต-ย่านใกล้อินฟราเรด (UV-NIR) และสเปกโทรสโกปีของการเรืองแสง (PL) เพื่อระบุถึงเฟสที่ได้ ลักษณะรูปร่าง ทิศทางการเติบโต การสั่นของแลตทิซ และสมบัติทางแสง ซึ่งควบคุมโดยชนิดและปริมาณของสารตั้งต้นที่ใช้ เวลาและอุณหภูมิในการเกิดปฏิกิริยา ในงานวิจัยนี้ยังได้เสนอกฎการกำเนิดโลหะซัลไฟด์ที่มีลักษณะรูปร่างต่าง ๆ กันที่สอดคล้องกับผลการทดลองนี้ รวมทั้งประโยชน์ของบิสมัทซัลไฟด์ ( $\text{Bi}_2\text{S}_3$ ) และคอปเปอร์ซัลไฟด์ ( $\text{CuS}$ ) ในเซลล์แสงอาทิตย์ชนิดสีย้อมไวแสงด้วย

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## ABBREVIATIONS AND SYMBOLS

|                    |   |   |
|--------------------|---|---|
| $^{\circ}\text{C}$ | = | Degree Celsius  |
| mm                 | = | Millimeter  |
| nm                 | = | Nanometer   |
| $\mu\text{m}$      | = | Micrometer  |
| $\text{\AA}$       | = | Angstrom  |
| mg                 | = | Milligram   |
| ml                 | = | Milliliter  |
| FT-IR              | = | Fourier-Transform Infrared Spectrometry                 |
| UV-NIR             | = | UV-Visible-Near IR Spectrometry                         |
| PL                 | = | Photoluminescence Spectrometry                          |
| SEM                | = | Scanning Electron Microscopy                            |
| TEM                | = | Transmission Electron Microscopy                        |
| XRD                | = | X-Ray Diffraction Spectrometer                          |
| JCPDS              | = | The Joint Committee for Powder<br>Diffraction Standards |
| DSSC               | = | Dye sensitized solar cell                               |
| HSSC               | = | Hybrid sensitized solar cell                            |
| SSSC               | = | Semiconductor sensitized solar cell                     |
| NCs                | = | Nanocrystals  |
| 0D                 | = | Zero dimension  |
| 1D                 | = | One dimension   |

|     |   |                          |
|-----|---|--------------------------|
| 2D  | = | Two dimension            |
| 3D  | = | Three dimension          |
| DOS | = | Density of state         |
| QD  | = | Quantum dot              |
| hcp | = | Hexagonal closed packing |
| ccp | = | Cubic closed packing     |
| HEC | = | Hydroxy ethyl cellulose  |
| PEG | = | Polyethylene glycol      |
| PVA | = | Polyvinyl alcohol        |
| PVP | = | Polyvinyl pyrrolidone    |