Code/Field of Science: 112/Kimia

RESEARCH PROPOSAL
INTERNATIONAL COLLABORATION RESEARCH
AND SCIENTIFIC PUBLICATION

DEVELOPMENT OF SOLID STATE DYE-SENSITIZED SOLAR CELL BASED ON NITROGEN-DOPED TiO_2

RESEARCH TEAM:
Dr. CAHYORINI KUSUMAWARDANI, M.Si (0023077704)
Prof. Drs. K.H. SUGIYARTO, M.Sc., Ph.D (0015094803)

UNIVERSITAS NEGERI YOGYAKARTA

OCTOBER 2014

LEMBAR PENGESAHAN
PENELITIAN KERJASAMA LUAR NEGERI DAN PUBLIKASI INTERNASIONAL

Title of Research	: Development of Solid State Dye-Sensitized Solar Cells Based on Nitrogen-doped TiO2
Code/Name of Field of science	: 112 / Kimia
Chief researcher:	
a. Full name	: CAHYORINI KUSUMAWARDANI M.Si.
b. NIDN	: 0023077704
c. Academic rank	: Lektor
d. Study program	: Biologi
e. Mobile phone	: 0818467905
f. E-mail	: cahyorini.k@uny.ac.id
Member of researcher (1)	:
a. Full name	: Prof.Drs. SUGIYARTO M.Sc.,Ph.D.
b. NIDN	: 0015094803
c. University	: Universitas Negeri Yogyakarta
International partner	
a. Full name	: Prof Wu Mingmei
b. Name of institution	: Sun Yat-sen University
c. Address of institution	: 135 West Xingang Road, Guangzhou, China
Length of research period	: 3 years
Year of research	: 2
Total research funds	: Rp 591.360.000,00 (US $ 49200)
Research funds of current year	: - to Dikti Rp 198.160.000,00 (US $ 16140)
	- Internal univ. Rp 0,00 (US $ 0)
	- Others Rp 0,00 (US $ 0)
	- Inkind chemical, analisis dan accommodation

Acknowledged
Dekan FMIPA UNY

(Dr Hartono)
NIP/NIK 196203291987021002

Yogyakarta, 27 - 10 - 2014
Chief researcher,

(CAHYORINI KUSUMAWARDANI M.Si.)
NIP/NIK 197707232003122001

Approved
Ketua LPPM

(Prof Dr Anik Ghufron, M.Pd)
NIP/NIK 196211111988031001

CONTENT LIST

COVER PAGE........ i
APPROVAL PAGE ii
CONTENT LIST.. iii
ABSTRACT... 1
CHAPTER 1.. 2
1.1 Background.. 2
1.2 The Aims of the Research.. 3
1.3 Urgency of the Research.. 4
CHAPTER 2 LITERATURE REVIEW... 6
2.1 Dye-sensitized Solar Cells (DSSC) 7
2.2 Solid State`Dye-sensitized Solar Cells (SSDSC)…………………………… 10
2.3 Roadmap of the Research.. 14
CHAPTER 3 RESEARCH METHODE……………………………………….. 15
3.1 Materials and Equipment………………………………………………….. 15
3.2 Research Work …………………………………………………………… 15
3.3 Systemathics of the Research……………………………………………… 21
3.4 Bagan Alir Penelitian ……………………………………………………… 22
CHAPTER 4 RESEARCH BUDGET AND SCHEDULE..................................... 23
4.1 Budget............. 24
4.2 Schedule............ 24
REFERENCE............ 25
ATTACHMENT
Attachment 1 Budget Justification
Attachment 2 Equipments
Attachment 3 Letter of Agreement
Attachment 4 Research Organization
Attachment 5 Curriculum Vitae
Attachment 6 Statement Letter of Chief Project

ABSTRACT

Photovoltaic technology, that converts sunlight to electricity, is a potential energy alternative to solve the future energy problem. The discovery of dye-sensitized solar cell (DSSC) based on titanium dioxide (TiO_2) by Oregan and Grätzel in 1991 with an efficiency of 11% gives a very promising breakthrough in the field of solar cells. It is inexpensive to prepare, environmentally friendly, and the light-weight thin-film structures are compatible with automated manufacturing (Grätzel, 2005). Despite offering relatively high conversion efficiencies for solar energy, typical dye-sensitized solar cells suffer from durability problems that result from the use of organic compounds as dye-sensitiser and liquid electrolytes. Consequently, it adversely affects long-term performance and durability.

This research proposes to develop an energy renewable source technology based on solar energy as the implementation one of the university ground research theme as stated in the Master Plan Research UNY. Kompleks N719, phorpyrine, CdS and ZnO_2 are use to sensitize N-TiO_2, while 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene (spiro-OMeTAD) will be used in the system as hole transport material. Basically the research aims to improve the power conversion efficiency of the solid state dye-sensitized solar cell device based on nitrogen doped TiO_2 (N-TiO_2). Nitrogen doping on TiO_2 (N-TiO_2) will allow the material to absorb a broad range of light energy, including energy from the visible region of the electromagnetic spectrum. This work focuses on the photovoltaic performance of SSDSC using diverse light absorbing materials, especially high extinction molar of ruthenium complex and quantum dot semiconductors. The first year research have resulted an optimum N-TiO_2 relating to the requirement as semiconductor at DSSC system. Some quantum dot semiconductor such as CdS, CdSe, PbS, PbSe, ZnS and ZnSe have been evaluated as sensitizer and showed great improvement in light absorbing property.

The target of the second year research are developing the solid state solar cells with the use of solid electrolyte applied in studied system from the first year. It also targets at least one journal international each year and one intellectual property rights at the end of the research. In addition, through this research it also expected to elaborate a mutually network and cooperation with Sun Yat-sen University for future research elaboration especially at solar cells field. Overall, the results of this research are expected to contribute to the sunlight utilization technology as a source of renewable energy. More specifically, this research is also expected to increase the participation of Universitas Negeri Yogyakarta in support of technology and national development.

CHAPTER 1
INTRODUCTION

1.1 Background

Photovoltaics is a promising renewable energy technology that converts sunlight to electricity, with broad potential to contribute significantly to solving the future energy problem that humanity faces (Li *et al.*, 2006; Gratzel, 2007). The first generation photovoltaic solar cells based on silicon cells, although able to achieve 24% efficiency but this requires complicated materials, processes and techniques of cells construction making it very expensive (Goncalves, 2002). The second generation solar cells using thin layer of polycrystalline semiconductor, such as CdTe and $CuIn_{1-x}Ga_xSe_2$ which is generally cheap, flexible and lightweight; however the efficiency lower than 1st generation cells and also the toxicity of the materials is often a significant problem (Ruhle *et al.*, 2010). To date, semiconductor solar cells dominate commercial markets, with crystalline Si having an 80% share; the remaining 20% is mostly thin film solar technology, such as CdTe and $CuIn_{1-x}Ga_xSe_2$ (Bisquert, 2011).

Currently, the third generation of solar cells based on nanostructured semiconductors, organic-inorganic composite material, was developed to achieve high efficiency with a more economical cost (Kamat, 2007). The discovery of dye-sensitized solar cell (DSSC) based on titanium dioxide (TiO_2) by Oregan and Grätzel in 1991 with an efficiency of 11% gives a very promising breakthrough in the field of solar cells. It is inexpensive to prepare, environmentally friendly, and the light-weight thin-film structures are compatible with automated manufacturing (Grätzel, 2005). Despite offering relatively high conversion efficiencies for solar energy, typical dye-sensitized solar cells suffer from durability problems that result from their use of organic liquid electrolytes containing the iodide/tri-iodide redox couple, which causes serious problems such as electrode corrosion and electrolyte leakage. Consequently, it adversely affects long-term performance and durability.

The efficiency and stability of DSSC system can be increase by the use of solid state organic or p-type conducting polymer hole-transport material (HTM) to construct a solid state dye-sensitized solar cells (SSDSC) (Moon, 2011). Spiro-OMeTAD and bis-EDOT are organic conducting polymer that provides highest performance in solid state solar cells. In comparison to the liquid electrolytes the efficiencies of SSDSC are inferior, they are around only 60% of the efficiencies obtained with the liquid electrolytes (Bach *et al.*, 2009). In optimizing the device performance and stability of SSDSC, various light harvesting systems are employed to enhance a photovoltaic performance and investigate their properties in SSDSC. The light respon of semiconductor could be improved by the use of sensitizer materials, including organic or organometalic dye, inorganic dye and quantum dot.

1.2 The Aims of the Research

This research basically aims to improve the power conversion efficiency of the SSDSC device based on nitrogen doped TiO_2 (N-TiO_2). Nitrogen doping on TiO_2 (N-TiO_2) will allow the material to absorb a broad range of light energy, including energy from the visible region of the electromagnetic spectrum. This work focuses on the photovoltaic performance of SSDSC using diverse light absorbing materials, especially high extinction molar of ruthenium complex. The quantum dot semiconductor sensitizer is also evaluated as alternative light absorbing materials instead of molecular sensitizers. The 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene (spiro-OMeTAD) will be used as HTM to substitute liquid electrolyte in conventional DSSC.

Specifically, this research on second year aims to:

1. construct DSSC based on ruthenium polypyridine complex-sensitized N-TiO_2.
2. construct DSSC based on nanocomposite CdS/N-TiO_2, CdSe/N-TiO_2, PbS/N-TiO_2, PbSe/N-TiO_2 and ZnO_2/N-TiO_2
3. construct SSDSC based resulted sensitized N-TiO_2 using spiro-OMeTAD as HTM.
4. result at least one international journal publication a year and at least one patent at the end of the research.
5. sustain the network and cooperation with School of Chemistry and Chemical Engineering, Sun Yat-sen University, China.

1.3 Urgency of the Research

The importance role of energy in national development technologies brings the new and renewable energy as one of the strategic technology development focus areas in the National Long-Term Development Plan/Rencana Pembangunan Jangka Panjang Nasional (RPJPN) 2005-2025 and National Policy and Strategy/ Kebijakan Strategi Nasional (Jakstranas 2010-2014). Based on the elaboration of strategic areas by Ditlitabmas DIKTI, Universitas Negeri Yogyakarta sets the new and renewable energy as one of the leading strategic issues in the Master Plan Research/Rencana Induk Penelitian with one of the research ground theme **the development of photovoltaic solar cells, lithium batteries and photobattery**.

This research proposes to develop a solid state dye-sensitized solar cells (SSDSC) based on N-TiO_2 as the implementation one of the university ground research theme as stated in the Master Plan Research UNY. N719 compleks, phorpyrine, CdS and ZnO_2 are use to sensitize N-TiO_2, while spiro-OMeTAD will use in the system as hole transport material. Unfortunately, the facilities and instrumen that available in Indonesia to investigate to solar cell system are still very limit. In order to overcome limitation of instrument and facilities in Indonesia and also to enhance the skill and knowledge in solar cells system, it is a need to make a collaborative research with other researcher and institution abroad.

SSDSC based on N-TiO_2 and sensitization method of N-TiO_2 using quantum dots semiconductor such as CdS and ZnO_2 resulting inorganic-organic hybrid material for solid state solar cells are the originality of this research. Based on the results of a patent search in the www.dgip.go.id database or several international patents database, there is undiscovered similar concept development and methods. Searching using www.google.com has found several publications on the development of N-TiO_2 material and nanocomposite pure TiO_2/ZnO with different synthesis methods, while the publication of research which combines the two concepts as well as on the application of solid state dye-sensitized solar cells have not been found.

The researcher team from UNY has met Prof Wu Mingmei from Sun Yat-sen University at a conference in Bangkok, Thailand. Through further contact and discuss, both parties intend to develop a join collaborative research on solar cells. The facilities and equipments at Laboratory of Inorganic and Synthesis Chemistry, School of Chemistry and Chemical Engineering, Sun Yat-sen University, China are highly suitable for solar cells research. Thus, both parties intend to develop a research to improve the efficiency and stability of solar cells system with developing the solid state dye-sensitized solar cells based on N-TiO_2. The researcher team from UNY has a good background in the N-TiO_2 synthesis, sensitization with ruthenium complex and organic dye, and DSSC construction, while Prof Wu Mingmei have a high experiences in quantum dot luminescent material synthesis and solid state solar cells. The research will be done at both institutions with possibilities of visiting each other. The more detailed research plan and the work place will be list at Chapter 3. The expenses of the research part that will be done at UNY are proposed to the collaborative research project, while all expense of the research part at Sun Yat-sen University will be fund by Prof Wu Mingmei including chemicals, instrumentations and all accommodation need.

The target of this research are developing the solid state solar cells based on N-TiO_2. This research also targeted at least one journal international each year and one intellectual property rights at the end of the research. In addition, through this research it also expected to elaborate a mutually network and cooperation with Sun Yat-sen University for future research elaboration especially at solar cells field. Overall, the results of this research are expected to contribute to the sunlight utilization technology as a source of renewable energy. More specifically, this research is also expected to increase the participation of Universitas Negeri Yogyakarta in support of technology and national development.

CHAPTER 2
LITERATURE REVIEW

The oil crisis in 1973 fueled a rapid research on photoelectrochemical cells (Kalyanadundaram, 1985). TiO_2 became the favored semiconductor for water photolysis following its use by Fujishima and Honda in 1972. The solution to the problem that narrow-bangap semiconductors for efficient absorption of sunlight are unstable against photo-corrosion came in the separation of optical absorption and charge-generating functions. An electron transfer sensitizer is used to absorb the visible light and inject charge carriers across the semiconductor-electrolyte junction into a substrate with a wide bandgap, which is stable. This concept leads to the development of ZnO-*sensitized solar cells* (Tsubomura *et al.*, 1976) dan *dye-sensitized solar cell*/DSSC (Oregan dan Gratzel, 1991).

In DSSC, the semiconductor is in the mesoscopic state: minutely structure with an enormous internal surface area and percolating nanoporous networks. The semiconductors (i.e. TiO_2, ZnO, SnO_2 and CdSe) films are made up of arrays of tiny crystals measuring a few nanometers across which are interconnected to allow electronic conduction to take place. This structure has a much larger surface area (over a thousand times) available for dye chemisorption than a flat, unstructured electrode. The photocurrent standard sunlight increased 10^3-10^4 times when passing from a single crystal to a nanocrystalline electroda. An overall power conversion efficiency of 10.4% has been obtained for DSSC (Green *et al.*, 2008; Nazeeruddin *et al.*, 2001). The record efficiency of DSSC is 12% for small cells and about 9% minimodules (Hagfeldt *et al.* 2010).

The successful of DSSC has rekindled interest to develop this system. Semiconductor sensitization is one of important component in the DSSC system because most metal oxide semiconductors (such as WO_3, Fe_2O_3 and TiO_2) only absorb UV light. First DSSC system, called as Gratzel cell, using TiO_2 electrode sensitized by ruthenium polypyridyne complexes, electrolyte redox solution and Pt-counter electrode. The use of organic compounds as a sensitizer provides a cheaper alternative, but the thermal stability of organic compounds is very low so susceptible to photodegradation.

Third generation solar cells are emerging as novel PV-technologies. Generally they tend to include polymer solar cells, dye-sensitized solar cells, quantum dot cells, tandem/multi-junction cells, up–down conversion technologies and hot-carrier cells (Nozik, 2002.). The name of third generation solar cells are given to devices aim to overcome the Shockley-Queisser limit of single junction or single band gap device (33.7%), even the limit of an infinite stack of band gaps that perfectly matched to the solar spectrum (68%), and large-scale implementation (Green, 2003). In principle, sunlight can be converted to electricity at efficiency close to Carnot limit of 93 %.

2.1 Dye-sensitized Solar Cells (DSSC)

Initial study of DSSC was based on flat electrodes, but these devices had an intrinsic problem. The light harvesting efficiency is extremely low because only the first layer of adsorbed dye lead to effective electron injection into the semiconductor. The photovoltaic performance was immensely improved by using a nanoporous electrode instead of the flat electrode. Since then, DSSC have been regarded as the next energy conversion device to substitute conventional Si solar cells. They are promising for low cost solar electricity generation owing to their cheap material and simple fabrication process. Already small cells reach over 11 % conversion efficiency (Hagfeldt *et al.*, 2010). They have not only high efficiency but also remarkable stability: more than 1000 hours at 60 ºC under continuous illumination of 1000 W/m^2 visible light with minor performance degradation. The principal work of DSSC showed in Figure 1.

The scheme of DSSC princip showed in Figure 1. DSSC has the following advantages comparing with the Si based photovoltaics: 1). It is not sensitive to the defects in the semiconductors such as defects in Si. It was found that the charge transport of photogenerated electrons passing the nanocrystalline particles and grain boundaries is highly efficient (Wurfel *et al.*, 2008); 2). The semiconductor-electrolyte interface (SEI) is easy to form and it is cost effective for production(Wei, 2010); 3). It is possible to realize the direct energy transfer from photons to chemical energy using nanoporous structures that offer a enormous surface area for the adsorption of dye molecules (Hagfeldt *et al.*, 2010); and 4). It is a cheaper alternative to silicon solar cells.

Because of the encapsulation problem posed by liquid in the conventional wet DSSC, much work has also been done on an all solid DSSC (Bach *et al.*, 1998; Tennakone *et al.*, 1998). To construct a full solid state DSSC, a solid p-type conductor should be chosen to replace the liquid electrolyte. The redox levels of the dye and p-type materials have to be adapted carefully to result in an electron in the conduction band of n-type semiconductor (e.g. TiO_2, ZnO) and a localized on the p-type conductor (e.g. CuI) (Tennakone *et al.*, 1998). Solid DSSC has also been fabricated using TiO_2 and conducting polymers such as polypyrrole (Murokashi *et al.* 1998), low bandgap polymer (Shin *et al.*, 2007), polyaniline (Ameen *et al.*, 2009) and polyvinyl pyridine (Kusumawardani *et al.*, 2012). Solid state DSSC based on ionic liquids were also reported to enhance the conversion efficiency and the non-volatile character of ionic liquids offers the easy packaging for printable DSSC (Wang *et al.*, 2003).

A challenging but realizable goal for the present DSSC technology is to achieve efficiencies above 15%. It requires developing dye-electrolyte system that give efficient generation of the oxidaized dye at a driving force of 0.2-0.4 V (Hagfeldt *at* al., 2010). The nanostructured TiO_2 electrode does not conduct any electrical current and itself is a very good insulator. The conventional N3 dye dissolved in a solution degrades after a few hours under light. But when these are brought together in a well-working device, the solar cell conducts electrical current up to 20 mA/cm^2 and the dye will stable for more than 15 years in outdoor solar radiation. Therefore, the photovoltaic function is the emergent property of the device that is made of the individual entities of the semiconductor, the sensitizer and the electrolytes.

The future directions for the development of DSSC include: 1) organic dyes that can extend light absorption into near infrared with good photo and thermal stability (Kalyanasundaram dan Gratzel, 1998); 2) synthesis and modification of various type of TiO_2, or other semiconductors nanomaterials (Chen dan Mao, 2006); and 3) modification of the physiscal properties of TiO_2 nanostructures to extend optical absorption into the visible region (Chen *et al.*, 2005; Khan *et al.*, 2002; Kusumawardani *et al.*, 2010).

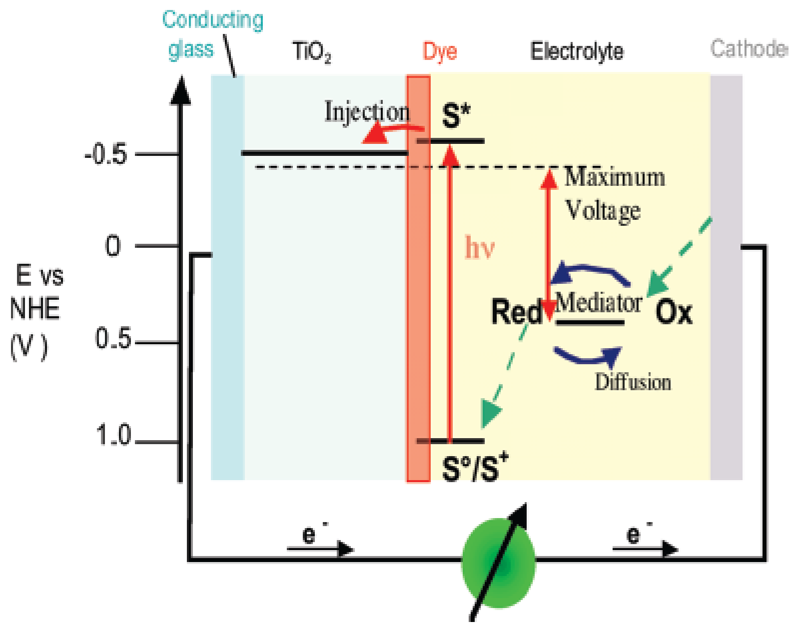


Figure 1. Work principal of system: DSSC

Development of organic dye continues to be done by adding transition metals in organic compounds to improve its stability when applied to DSSC (Zoha *et al.*, 2006). The development of DSSC has been done by several research groups, among others Grätzel *et al.* (2005) who developed the Ru-polipiridin complex as efficient sensitiser. Several groups of researchers also developed a method of mesoporous TiO_2 synthesis with various techniques for DSSC applications resulted efficiencies up to 9% (Kusumawardani *et al.*, 2007). Modification of TiO_2 nanoparticles by doping metal ions such as Zn^{2+} and Pb^{2+} at DSSC system initiated by Elif Arici, *et al.* (2004) provide a response photovolatic with external efficiencies up to 12%. Although the efficiency is quite high but the stability dropped when the temperature of radiation was increases, because the metal ions become an electron-hole recombination centers and less optimal penetration of the dye complex on the semiconductor surface.

Another effort to improve the efficiency and stability of DSSC is using a non metal doping semiconductor such as nitrogen-doped TiO_2. The use of nitrogen doped TiO_2 in DSSC system conducted by Ma *et al.* (2005) provide much higher efficiency and stability (8% efficiency and the stability up to 2000 hours) than pure TiO_2 (3.6% efficiency and 680 hours of stability for pure TiO_2). Kusumawadini *et al.* (2010) also have made use of N-TiO_2 as the semiconductor of DSSC produced the highest cell efficiency of 6.4%, 30% higher than pure TiO_2 based DSSC efficiency (5.1%).

Current study of DSSC based on CdS sensitized TiO_2 thin films which synthesized through chemical bath deposition method and using I^-/I_3^- electrolyte resulting conversion efficiancy around 10.4% (Dor *et al.*, 2009). The valence band and the conduction band level of the quantum dots plays an important role in the capture of electrons and holes that occur at the interface. CdSe and CdTe quantum dots has been reported to bind strongly to TiO_2 through a linker molecules and inject electrons into the conduction band of TiO_2 at an exponential rate below bandgap excitation (Bang dan Kamat, 2009). CdTe has a more negative conduction band (-1.25 V versus the normal hydrogen electrode) than CdSe (-1.2 V versus the normal hydrogen electrode) and therefore can inject electrons into TiO_2 at a faster rate. Nevertheless, SSDSC CdTe-based solar cell efficiencies are lower (7.8%) compared to CdSe (9.1%) due to the position of CdSe valence band energy level (0.53 V) is higher than CdTe (0.1 V) so that some electrolyte pair easier to fill the void of electrons (holes) in CdSe than CdTe. CdSe therefore more likely to be used as a sensitiser TiO_2 on DSSC.

2.2 Solid State Dye-sensitized Solar Cells (QDSSC)

Dye-sensitized solar cells have numerous advantages such as cheap materials, simple manufacturing process, lightweight, and environmental-friendly technology, etc. However, liquid electrolyte-based devices have not attained wide-spread applications in the commercial market due to concerns of solvent leakage and corrosion problems from the iodide/triiodide redox couple. Many approaches to replace liquid electrolyte have been researched, for instance polymer electrolyte, ionic liquids, p-type semiconductors such as CuI or CuSCN and organic hole conductors (Moon, 2011). Recently, the conversion efficiency of the SSDSC based on an organic hole conductor have achieved over 8 % PCE (Zhang *et al.*, 2010). These interesting results have stimulated research on the SSDSC. It was Tennakone *et al.* (1988) reported for the first time a solid-state dye-sensitized heterojunction between TiO_2 and CuSCN. However sensitized photocurrents were still low due to the nonporous structure of the junction. Alternative approaches were undertaken to form solid-state dye-sensitized junctions, employing either wide bandgap semiconductors or organic semiconductors.

SSDSC possess a monolithic structure in contrast to the sandwich design of the liquid electrolyte based DSSC. In Figure 2, the other processes such as photoexcitation of sensitizer, electron injection and dye regeneration are the same as in the liquid electrolyte-based DSC: the only different part is that hole transfer takes place directly from the dye to the HTM, and then the hole is transported via hopping to the counter electrode.

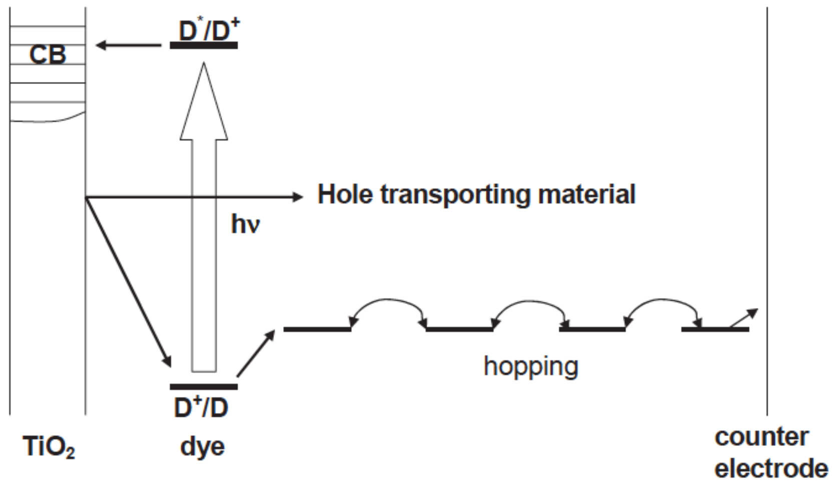


Figure 2 Scheme for the electron transfer processes of the SSDSC

Inorganic solid-state dye-sensitized solar cells

In this approach a monolayer of dye is sandwiched between two inorganic wide bandgap semiconductors, while one of them exhibits a p-type and the other an ntype conduction mechanism. While wide bandgap n-type semiconductors are widely used, only few wide bandgap p-type semiconductors are known. Out of these Cu(I)SCN and Cu(I)I proved to be appropriate for their use in dye-sensitized solid-state junctions. A potential advantage of inorganic semiconductors is their generally high charge mobility compared to organic semiconductors. However the very limited choice of potentially interesting materials is a clear drawback, compared to the nearly unlimited choice of organic charge transport materials.

Despite the apparent inconveniences of all-inorganic sensitized junctions their photon-to-electron conversion efficiencies have drastically increased over the past years. O'Regan *et al.*5 recently reported on a system based on an electrodeposited layer of ZnO, sensitized with a phosphonated ruthenium polypyridyl complex. The heterojunction is finally formed by electrodeposition of CuSCN, growing inside the porous ZnO structure. White light solar energy conversion efficiencies of up to 6.5 % and photon-to-electron conversion efficiencies of up to 45 % have recently been obtained by such systems.

Inorganic/organic solid-state dye-sensitized solar cells

Low molecular weight charge transport materials as well as semiconducting polymers were applied in such junctions. Hagen *et al.* (2008) were the first to report on a solid-state device based on a molecular semiconductor, which was applied to a $Ru(dcbpy)_2(SCN)_2$ sensitized nanocrystalline TiO_2 electrode via thermal evaporation. However energy conversion efficiencies were still low (IPCE < 0.2). The first solid-state dye-sensitized heterojunction of TiO_2 and a semiconducting polymer was reported by Yanagida and co-workers (2005(. They formed a solid-state heterojunction by electrodeposition of polypyrole into a nanoporous TiO2 structure, sensitized with $Ru(dcbpy)_2(SCN)_2$. Solar energy conversion efficiencies were somewhat higher than for the system but still did not exceed 0.1 %. A thin film composite device was described recently by Kocher *et al.* (2010), comprising a blend of dye-sensitized TiO_2 particles, a conducting polymer (LPPP) and C60. However, an external bias was necessary to sustain a measurable photocurrent. This might be due to insufficient interparticle contact or insufficient doping of the device.

Hole Transporting Material (HTM)

The HTM should be able to transfer holes from the dye after the dye has injected electrons in the TiO2. Several criteria have to be considered for the material to function as a good HTM. For efficient dye regeneration, the upper edge of the HTM valence band must be located above the ground state level of the dye. Moreover, the HTM must have a good contact with porous TiO_2 layer by penetrating into the pores of the nanoparticle film, and finally it should be transparent to the visible spectrum, where the dye absorbs light. There are two types: organic and inorganic HTM.

CuI (Tennakoke *et al.*, 1999; Shirimanne *et al.*, 2003; Kumara *et al.*, 2002) and CuSCN (Oregan *et al.*, 2002; Oregan and Schwartz, 1995; Itzhaik *et al.*, 2009) are the representative inorganic HTM. These copper-based materials can be cast from solution or vacuum deposition to form a complete hole-transporting layer. Also they have good conductivity over 10^{-2} S/cm, which facilitates their hole conducting ability. They showed relatively good power conversion efficiencies over 2 % when used in a SSDSC. However, the SSDSC devices based on these inorganic hole conductors have problems such as instability, crystallization on TiO_2 film surface before penetrating into the pores and insufficient pore-filling.

Organic HTM possess the advantages of low crystallinity, easy film formation and plentiful sources. The first efficient SSDSC using organic HTM, 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene (spiro-OMeTAD) was reported by Udo *et al*. in 1998. Utilization of additives, $Li(CF_3SO_2)_2N$ and 4-*tert*-butylpyridine, in spiro-OMeTAD solution increased the short circuit current and the open circuit voltage and led to an enhancement of the power conversion efficiency in SSDSC (Kruger *et al.*, 2001). Recently, a SSDSC based on spiro-OMeTAD achieved the highest efficiency of over 6 % with a high extinction coefficient organic dye.

Charge recombination occurs easily in SSDSC due to the high proximity of electrons and holes throughout the networks and the lack of substantial potential barrier at the interface. As a result, it is a main loss factor and leads to a low fill factor and open circuit voltage loss. The charge recombination between the oxidized dye molecule and the injected electron into TiO_2 is negligible in SSDSC, since the oxidized dye molecule is regenerated by the HTM at a high rate, typically at the nanosecond time scale. There is another kind of charge recombination between injected electrons in the TiO_2 and holes in the HTM, and this back reaction takes place dominantly in SSDSC. Surface modification of the nanocrystalline TiO_2 layer is a versatile technique to suppress charge recombination. One of the most researched ways is the TiO_2 surface coating with insulator such as ZrO_2 (Palomares *et al.*, 2002), ZnO (Tennakone *et al.*, 1999), or MgO (Jung *et al.*, 2005) to retard the recombination

(Diamant *et al.*, 2004). The insulating layer can block the access of holes to recombination centers on the TiO2 surface. Instead of an insulator, using a co-adsorbent with the dye can make the same effect by creating an insulating thin layer. Recently, Wang *et al*. (2010) reported effectively reduced recombination using 4-guanidinobutryc acid (GBA) as a co-adsorbent with Z907 sensitizer in the SSDSC device. Dye designs such as donor-antenna dye or dipolar dye molecule also have an influence on the charge recombination by controlling charge transfer dynamics.

2.3 Roadmap of the Research

Research on improving the efficiency and stability of solar cells continues to grow rapidly with the increasing world energy consumption. The last few years, researcher team focuses on the proponent development of photovoltaic solar cell technology in line with the umbrella research theme of UNY Research Master Plan. First research was done to develop DSSC based on metal polypyridine complex sensitized TiO_2 (Kusumawardani *et al.*, 2007). These research produce TiO_2 nanoparticles and its application on DSSC system with efficiency of 4%. Further research was TiO_2 nanostructure modification with nitrogen doping (N-TiO_2) to enhance the optical absorption of TiO_2. The DSSC system based on N-TiO_2 has higher efficiency and stability than DSSC system based on pure TiO_2 (Kusumawardani *et al.*, 2010).

The researcher team has also developed a new sensitization method through *in situ* formation of ruthenium complexes on N-TiO_2 surface (Kusumawardani *et al*., 2011). It was also investigated the development of hybrid solar cells to overcome the problem of liquid electrolyte (Kusumawardani *et al.*, 2012). Since there are many limitation on laboratory facilities and solar cells tested instrument, some of those research sample should be sent abroad for analysis. Therefore, it is a need to develop a kind of collaboration with expert researcher from institution abroad to explore further research on solar cell technology through a joint research.

CHAPTER 3
RESEARCH METHOD

3.1 Equipments and Materials

1. **The Main Equipment:** Glass equipment, vessel Teflon, Oven, Muffle furnace, Sonication Bath, *Sprayer* and instrumentation analysis such as XRD, UV-Vis diffuse reflectance, solar cell testing, etc

2. **The Main Materials:** Titanium Tetraisopropoxide (TTIP), dodecylamine (DDA), acetic acid glacial, redox electrolyte, ITO, HCl, spiro-OMeTAD, phorpyrine, ruthenium complex, quantum dot precursor.

3.2 Research Work

This research will be plan at three step during three years as follow and the work method at second year as follow:

1. **Synthesis of nanocomposite CdS/N-TiO_2 and ZnO_2/NTiO_2**

The quantum dot material will *in-situ* synthesized at N-TiO_2 surface to obtain a better contact between N-TiO_2 and quantum dot material using *dip coating* and *chemical bath deposition*.

a. *dip coating method*

N-TiO_2 thin film is immerse at 0.2 M $CdCl_2$ solution for 5 minute then rinse with water, then continue to immerse at 0.2 M Sodium selenosulphate for 5 minutes and rinse with water (sumber Se). This procedure called one cycle, the number of the cycle is vary to obtain the thickness and the sum of deposited quantum dot.

b. Metode *chemical bath deposition*

At this method, all reactants are mix together at the beginning of the synthesis. N-TiO_2/CdS is prepared by adding excess Cd^{2+} with complexing agent triethanolamine (TEA) and release slowly as free Cd ion to react with selenide that exist in the solution. The mix precursor solution contains 1 M $CdCl_2$, 1 M NaOH, 1 M thiourea, 1 M TEA and water. The

N-TiO_2 thin film is then immersed at this precursor solution varies at 10 minute up to some hours. Afterwards, the substrate is cleaned using 1 M HCl and heated at 150^{o}C for 30 menit.

- *ZnO_2*

In a typical procedure, 30 mmol sodium oleate, 6 ml of water, 12 ml of ethanol, and 26 mmol oleic acid were mixed together under agitation to form a homogeneous solution. Then 1 mmol (total amounts) of $Zn(NO_3)_2$ aqueous solution was added with magnetic stirring. The mixture was agitated for about 10 min, then transferred to a 50 ml autoclave, sealed, and hydrothermally treated at 120–190 ^{o}C for 3–48 h. The system was allowed to cool naturally to room temperature, and the products were deposited at the bottom of the vessel. Cyclohexane was used to collect the products deposited in the vessel and ethanol was added to the deposited products. The precipitates were separated by centrifugation, washed with deionized water and ethanol in sequence several times, and then dried in a vacuum.

The quantum dot sensitization will be done through electrophoretic deposition following procedure that developed by Salant *et al.*, 2010. Electrodes QDs were diluted in toluene, with concentrations of ∼2.2 × 10−6 M. Two TiO_2 ITO electrodes were immersed vertically in the QD solution parallel to each other. The deposition area of the electrodes was about 0.25 cm^2, and the distance between them was adjusted at 1 cm. A voltage of 200 V was applied for 5−90 min. QDs were deposited on both the cathode and anode electrodes. Fresh layers at each deposition time were taken from the electrophoretic cell, rinsed several times with toluene to wash off unbound QDs, subsequently rinsed with ethanol, and dried at room temperature. After electrophoretic deposition colloidal QDs were coated with a CdS layer grown by SILAR.

2. Sensitization of N-TiO_2 thin film

The dye sensitization of N-TiO_2 thin film will be done through chemical bath deposition. Before applying N-TiO_2 thin film to ruthenium complex and organic dyes, the thin film is heated at 80 ^{o}C for 30 minutes. When the TiO_2 film was taken out of the oven, while it still hot, it was dipped into a 1 mM ethanolic solution of ruthenium complex or phorpyrine and was left there for about 16 h. Then, the dye-coated electrode was copiously washed with ethanol and dried in a stream of N_2.

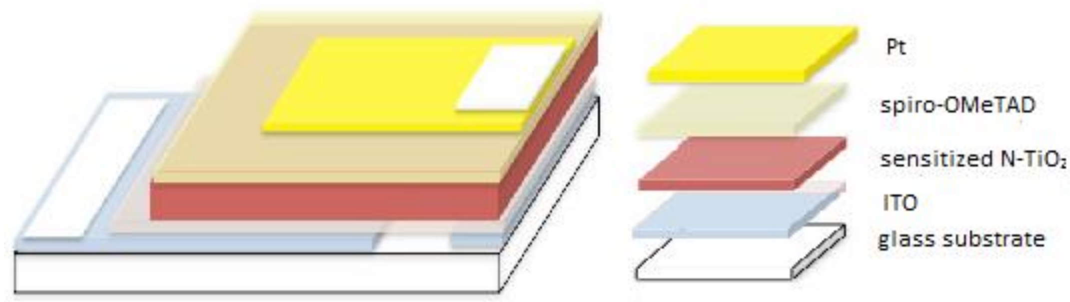
3. **Optimization of N-TiO_2 sensitization**

The parameter that will be optimized including:

- The thickness of N-TiO_2 thin film
- Sensitizer concentration
- Cycle and deposition time

4. **Solid State Solar Cells Construction**

The SSDSC is construct following the schematic:



SSDSC is constructing from sensitized-N-TiO_2 QDSSC and Pt counter electrode assembled a sandwich-type configuration. Before applying to the sandwich structure the spiro-OMeTAD electrolyte are coated on sensitized N-TiO_2 layer. Between two electrodes is place the *thermoplastic sealant film spacer* (thickness of ~50µm) to hind the conslerting.

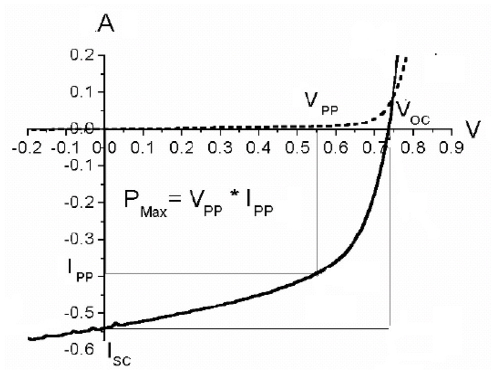
5. **Photovoltaic Testing**

IPCE. The IPCE instrument (Solar Cell Scan100) is calibrated using normalized silicon cell before use to measure the IPCE of constructed cell. The IPCE is measure at the wavelength of 350–800 nm resulted from 300 Watt Xenon *Arc Research Source* lamp that focused power equivalent to 100 W/m^2 with solar radiation of AM 1.5. The instrument is using MS 260i to result monochromatic light. The IPCE is measured following equation:

$$\%IPCE = \frac{I_{SC}}{P_{inc}} . \frac{1240}{\lambda} .100\%$$

with I_{sc} is short current (μA/cm^2), P_{inc} is monochromatic power (W/cm^2) and λ is the monochromatic wavelength (nm).

<u>Current-Voltase measurement (I-V).</u> The I-V curve is measured using Kethley 2200 instrument, with solar simulator (10500 Abet Tech.) that emitting light at AM 1,5D and light intensity 160 mW/cm^2. The I-V is measured at the condition with and without illumination to obtain the following curve:



P_{max} is maximum output of solar cells sample. Based on I-V curve, the *fill factor* (FF) and solar cell efficiency (η) could be determined following equation:

$$FF = \frac{P_{\max}}{V_{oc} I_{sc}} = \frac{V_{PP} I_{PP}}{V_{oc} I_{sc}}$$

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{inc}}.100\%$$

With V_{pp} = maximum voltase (V); I_{pp} = maximum current (mA/cm^2); I_{sc} = short current (mA/cm^2); V_{oc} = *open circuit* V and P_{inc} = light intensity (W/cm^2)

<u>Year III</u>

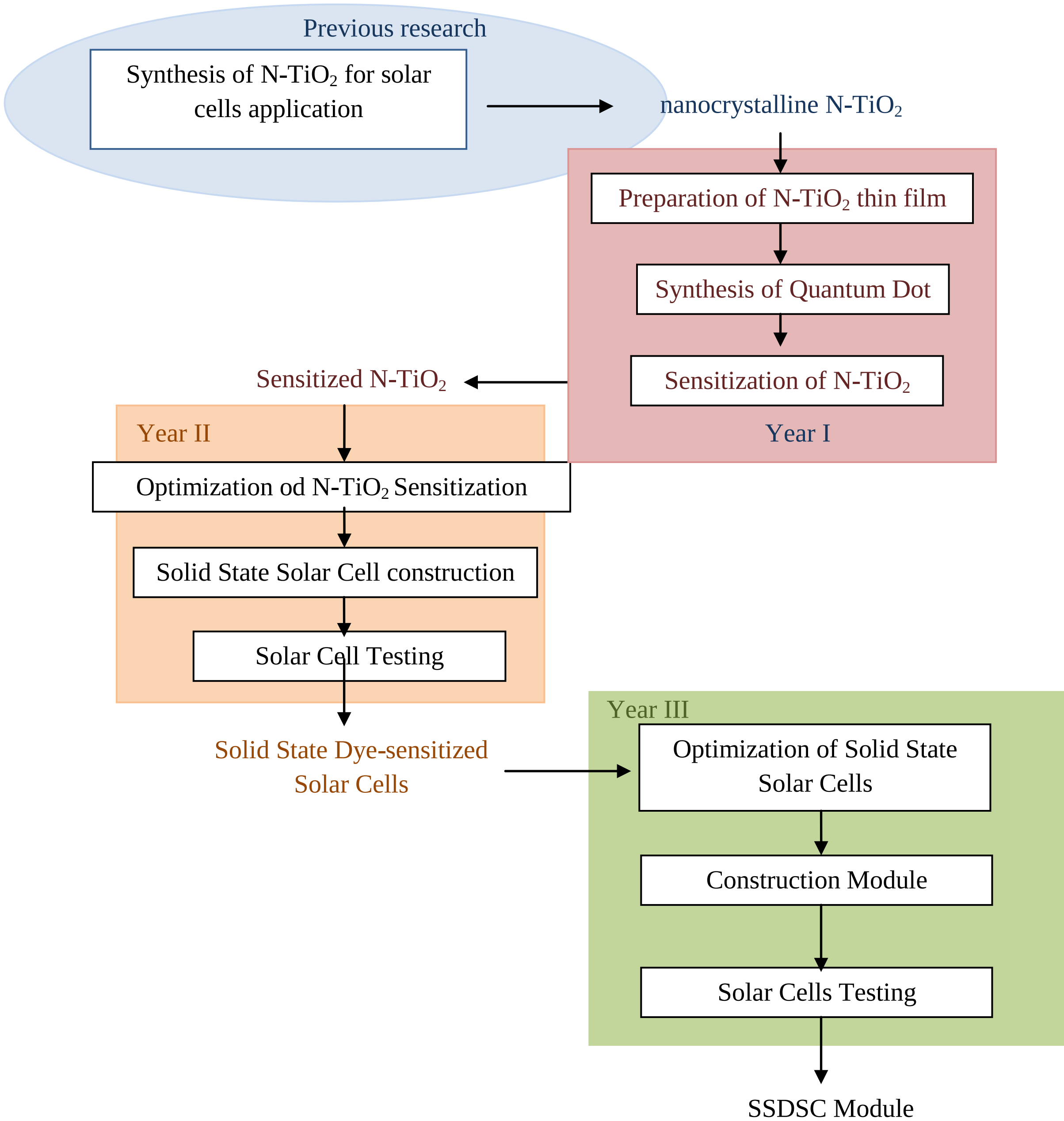
Research on year 3 will optimize the SSDSC based on N-TiO_2 and mini module construction to direct testing under solar energy.

a. The Systematic of the Research

The second year research will be done as following systematic:

No	Activity and scope of the research	Work Place	Success indicator	Outcome
1	Sensitization of N-TiO_2	Universitas Negeri Yogyakarta	Sensitized-N-TiO_2 thin film	Article about sensitized-N-TiO_2 thin film (international journal)
2	Optimization of N-TiO_2 sensitization (second year)	Universitas Negeri Yogyakarta and Sun Yat-sen University	Sensitized-N-TiO_2 thin film	Article about Sensitized-N-TiO_2 thin film and its characterization
3	Construction of solid state solar cell based on sensitized-N-TiO_2 thin film (second and third year)	Universitas Negeri Yogyakarta	Solid state solar cell based on sensitized-N-TiO_2 thin film	Article about solid state solar cell based on sensitized-N-TiO_2 thin film (international journal)
4	Optimization of solid state solar cell based on sensitized N-TiO_2 (second and third year)	Universitas Negeri Yogyakarta and Sun Yat-sen University	Optimum solid state solar cell based on sensitized N-TiO_2	Article about optimum solar cell based on sensitized N-TiO_2 (international journal and patent)
5	Construction of solid sate solar cell mini module based on solid state sensitized N-TiO_2 (third year)	Universitas Negeri Yogyakarta	solid state solar cell based on sensitized N-TiO_2	Article about mini module solid state solar cell based on sensitized N-TiO_2 (international journal)
6	Optimation of solid sate solar cell mini module based on solid state sensitized N-TiO_2 (third year)	Universitas Negeri Yogyakarta and Sun Yat-sen University	Optimum solid state solar cell based on sensitized N-TiO_2	Article about optimum mini module solid state solar cell based on sensitized N-TiO_2 (international journal)

b. Flow Chart of the Research



CHAPTER 4
RESEARCH BUDGET AND SCHEDULE

4.1 Budget

No	Item	Year II (Rp)	Year III (Rp)
1	Honorarium	46.200.000	46.200.000
2	Equipments	37.200.000	29.800.000
3	Materials	48.560.000	52.830.000
4	Transportation	39.200.000	38.000.000
5	Administration, publication, etc	27.000.000	29.500.000
Total per year		198.160.000	198.330.000
Total all years		591.360.000	

Detailed budget justification will available at Attachment 1

4.2 Research Schedule

No	Work	Year II										Year III											
		9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	Research Coordination		■	■			■			■			■	■			■			■			■
2	Equipment and Material			■	■									■	■								
3	Optimization of N-TiO_2 sensitization	■			■	■																	
4	Solar cells construction					■	■	■															
5	Solar Cells optimation							■	■	■	■	■		■	■								
6	Solar Cells module construction														■	■	■	■					
7	Solar Cells module optimation																■	■	■	■	■	■	
8	Test and characterization	■				■	■	■		■	■	■				■	■	■	■	■	■	■	
9	Research progress reporting							■										■					
10	Publication writing and submiting	■	■					■				■	■					■				■	■
11	Final year report	■	■									■	■									■	■

REFERENCES

Ameen, S., Akhtar, M. S., Kim, G. S., Kim, Y. S., Yang, O. B., & Shin, H. S., 2009, Plasma-Enhanced Polymerized Aniline/TiO_2 Dye-Sensitized Solar Cells, *J. Alloys Comp.*, 8, 7, 1-7

Bach, U., Lupo, D., Comte, P., Moser, J. E., Weissortel, F., Salbeck, J., *et al*,. 1998, Solid-State Dye-Sensitized Mesoporous TiO_2 Solar Cells with High Efficiencies, *Nature*, 395, 6702, 583-585

Bang, J. H., & Kamat, P. V., 2009, Quantum Dot Sensitized Solar Cells. A Tale of Two Semiconductor Nanocrystals: Cdse and Cdte, *Acs Nano*, 3, 6, 1467-1476

Bisquert, J., 2011, Dilemmas of Dye-sensitized Solar Cells, *Chem. Phys. Chem.*, 12, 1633-1636

Chen, X. B., Lou, Y. B., Samia, A. C. S., Burda, C., & Gole, J. L., 2005, Formation of Oxynitride as the Photocatalytic Enhancing Site in Nitrogen-Doped Titania Nanocatalysts: Comparison to a Commercial Nanopowder, *Advanced Functional Materials*, 15, 1, 41-49

Chen, X., & Mao, S. S., 2007, Titanium Dioxide Nanomaterials: Synthesis, Properties, Modifications, and Applications, *Chem. Rev.*, 107, 7, 2891-2959

Dor, R., Subasri, R., Radha, K., & Borse, P. H., 2011, Synthesis of Solar Active Nanocrystalline Ferrite, MFe_2O_4 (Ca, Zn, Mg) Photocatalyst by MicrowaveIradiation, *Solid State Comm.*, 151, 6, 470-473

Gimenez, S., Mora-Sero, I., Macor, L., Lana-Villarreal, T., Gomez, R., *et al.*, 2009, Improving the Performance of Colloidal Quantum-Dot-Sensitized Solar Cells. *Nanotech.*, 20, 29, 0957-4484

Goncalves, L. M., Bermudez, V. D., Ribeiro, H. A., & Mendes, A. M., 2008, Dye-Sensitized Solar Cells: A Safe Bet for the Future, *Energy & Environ. Sci.*, 1, 6, 655-667

Gorer, S., & Hodes, G., 1994, Quantum-Size Effects in the Study of Chemical Solution Deposition Mechanisms of Semiconductor-Films, *J. Phys. Chem.*, 98, 20, 5338-5346

Gratzel, M., 2005, Conversion of Sunlight to Electric Power by Nanocrystalline Dye-Sensitized Solar Cells. *J. Photochem. Photobio.*,164, 1-3

Gratzel, M., 2007, Photovoltaic and Photoelectrochemical Conversion of Solar Energy, *Phil.Trans. Royal Sc.*, 365, 1853, 993-1005

Green, M. A., 2003, *Third Generation Photovoltaics: Advanced Solar Energy Conversion*, Springer-Verlag, Berlin, Heidelberg

Green, M. A., Emery, K., Hishikawa, Y., & Warta, W., 2008, Solar Cell Efficiency Tables, *Prog. in Photovoltaics*, 16, 5, 435-440

Guijarro, N., Lana-Villarreal, T., Mora-Sero, I., Bisquert, J., & Gomez, R., 2009, Cdse Quantum Dot-Sensitized TiO_2 Electrodes: Effect of Quantum Dot Coverage and Mode of Attachment, *J. Phys. Chem. C*, 113, 10, 4208-4214

Hagfeldt, A., Boschloo, G., Sun, L. C., Kloo, L., & Pettersson, H., 2010, Dye-Sensitized Solar Cells, *Chem. Rev.*, 110, 11, 6595-6663

Hensel, J., Wang, G. M., Li, Y., & Zhang, J. Z., 2010, Synergistic Effect of Cdse Quantum Dot Sensitization and Nitrogen Doping of TiO_2 Nanostructures for Photoelectrochemical Solar Hydrogen Generation. *Nano Letters*, 10, 2, 478-483

Hodes, G., 2008, Comparison of Dye- and Semiconductor-Sensitized Porous Nanocrystalline Liquid Junction Solar Cells, *J. Phys. Chem. C*, 112, 46, 17778-17787

Kalyanasundaram, K., 1985, Photoelectrochemical Cell Studies with Semiconductor Electrodes - a Classified Bibliography (1975-1983), *Solar Cells*, 15, 2,93-156

Kalyanasundaram, K., & Gratzel, M, 1998, Applications of Functionalized Transition Metal Complexes in Photonic and Optoelectronic Devices, *Coord. Chem. Rev.*, 177, 347-414

Kamat, P. V., 2007, Meeting the Clean Energy Demand: Nanostructure Architectures for Solar Energy Conversion, *J. Phys. Chem. C*, 111, 7, 2834-2860

Klimov, V. I., 2006, Detailed-Balance Power Conversion Limits of Nanocrystal-Quantum-Dot Solar Cells in the Presence of Carrier Multiplication, *Applied Physics Letters*, 89, 12, 123118

Kusumawardani, C., Wahyuningsih, S., Kartini, I & Narsito, 2007, Sol gel synthesis of Fe^{2+} polipiridil sensitized TiO_2 for DSSC Application, Proceeding of ICYC, Universiti Sains Malaysia

Kusumawardani, C., Kartini, I & Narsito, 2010, Synthesis of Nanocrystalline TiO_2 and Its Application on High Efficiency DSSC, *Ubon Ratch. J. Sci. Tech.*, 3, 1, 1-9

Kusumawardani, Kartini, I & Narsito, 2011, In situ rutenium polipirin complex formation on N-TiO_2 as fotoanode semiconductor DSSC system, *Proceeding of 1st SIECPC*, KACST, Saudi Arabia

Kusumawardani,C., Wahyuningsih, S., & Suwardi, 2012, Hybrid Solar Cells based on polivinil electrolyte, *Thammasat Int. J. Sci. Tech*., article in press

Lee, H. J., Yum, J. H., Leventis, H. C., Zakeeruddin, S. M., Haque, S. A., Chen, P., 2008, Cdse Quantum Dot-Sensitized Solar Cells Exceeding Efficiency 1%, *J. Phys. Chem. C*, 112, 30, 11600-11608

Li, B., Wang, L. D., Kang, B. N., Wang, P., & Qiu, Y., 2006, Review of Recent Progress in Solid-State Dye-Sensitized Solar Cells. *Solar Energy Materials and Solar Cells*, 90, 5, 549-573

Ma Tingli, L.; Akiyama, M.; Abe, E. and Imai, I., 2005, High-Efficiency Dye-Sensitized Solar Cell Based on a Nitrogen-Doped Nanostructured Titania Electrode, *Nano Letter*, 5, 12, 2543–2547

Mora-Sero, I., Gimenez, S., Moehl, T., Fabregat-Santiago, F., Lana-Villareal, T., Gomez, R., 2008, Factors Determining the Photovoltaic Performance of a Cdse Quantum Dot Sensitized Solar Cell: The Role of the Linker Molecule and of the Counter Electrode, *Nanotech.*, 19, 42, 4484

Murakoshi, K., Kogure, R., Wada, Y., & Yanagida, S., 1998, Fabrication of Solid-State Dye-Sensitized TiO_2 Solar Cells Combined with Polypyrrole, *Solar Energy Mater. Solar Cells*, 55, 1-2, 113-117

Nazeeruddin, M. K., Pechy, P., Renouard, T., Zakeeruddin, S. M., Humphry-Baker, R., Comte, P., *et al*. 2001, Engineering of Efficient Panchromatic Sensitizers for Nanocrystalline Tio2-Based Solar Cells, *JACS*, 123, 8, 1613-1624

Nozik, A. J., 2002, Quantum Dot Solar Cells. *Physica E-Low-Dimensional Systems & Nanostructures*, 14, 1-2, 115-120

Oregan, B., & Gratzel, M. (1991). A Low-Cost, High-Efficiency Solar-Cell Based on Dye-Sensitized Colloidal TiO_2 Films, *Nature*, 353, 6346, 737-740

Robel, I., Subramanian, V., Kuno, M., & Kamat, P. V., 2006, Quantum Dot Solar Cells. Harvesting Light Energy with CdSe Nanocrystals Molecularly Linked to Mesoscopic TiO_2, *JACS*, 128, 7, 2385-2393

Ruhle, S., Shalom, M., & Zaban, A., 2010, Quantum-Dot-Sensitized Solar Cells, *Chemphyschem*, 11, 11, 2290-2304, 1439-4235

Shin, W. S., Kim, S. C., Lee, S. J., Jeon, H. S., Kim, M. K., Naidu, B. V. K., *et al.*, 2007, Synthesis and Photovoltaic Properties of a Low-Band-Gap Polymer Consisting of Alternating Thiophene and Benzothiadiazole Derivatives for Bulk-Heterojunction and Dye-Sensitized Solar Cells, *Journal of Polymer Science Part a-Polymer Chemistry*, 45, 8, 1394-1402

Tennakone, K., Kumara, G., Kottegoda, I. R. M., Wijayantha, K. G. U., & Perera, V. P. S., 1998, A Solid-State Photovoltaic Cell Sensitized with a Ruthenium Bipyridyl Complex, *J. Phys.D-Applied Phys.*, 31, 12, 1492-1496

Tisdale, W. A., Williams, K. J., Timp, B. A., Norris, D. J., Aydil, E. S., & Zhu, X. Y., 2010, Hot-Electron Transfer from Semiconductor Nanocrystals, *Science*, 328, 5985, 1543-1547

Tsubomura, H., Matsumura, M., Nomura, Y., & Amamiya, T., 1976, Dye Sensitized Zinc-Oxide - Aqueous-Electrolyte - Platinum Photocell. *Nature*, 261, 5559, 402-403

Wei, D., 2010, Dye Sensitized Solar Cells. *Inter. J. of Molec. Sci.*, 11, 3, 1103-1113

Wurfel, U., Peters, M., & Hinscht, A., 2008, Detailed Experimental and Theoretical Investigation of the Electron Transport in a Dye Solar Cell by Means of a Three-Electrode Configuration, *J. Phys. Chem. C*, 112, 5, 1711-1720

Yin, L., & Ye, C., 2011, Review of Quantum Dot Deposition for Extremely Thin Absorber Solar Cells, *Science of advanced materials*, 3, 7, 41-58

Yu, W. W., Qu, L. H., Guo, W. Z., & Peng, X. G., 2003, Experimental Determination of the Extinction Coefficient of Cdte, Cdse, and Cds Nanocrystals, *Chem. Mater.*, 15, 14, 2854-2860

Zhang, Q. X., Guo, X. Z., Huang, X. M., Huang, S. Q., Li, D. M., Luo, Y. H., *et al.*, 2011, Highly Efficient Cds/Cdse-Sensitized Solar Cells Controlled by the Structural Properties of Compact Porous TiO_2 Photoelectrodes. *Physical Chemistry Chemical Physics*, 13, 10, 4659-4667

Attachment 1

Justification of Research Budget

1. Honorium					
Honorarium	Honorarium/hours (Rp)	Time (hour/week)	week	Honorarium per year (Rp)	
				Year 2	Year 3
Project Leader	22.000	15	40	14.200.000	14.200.000
Member 1	20.000	15	40	13.000.000	13.000.000
Technician 1	15.000	15	40	9.500.000	9.500.000
Technician 2	15.000	15	40	9.500.000	9.500.000
			SUBTOTAL (Rp)	46.200.000	46.200.000
2. Equipment					
Material	Usage Justification	Quantity	Unit Price (Rp)	Equipment Budget (Rp)	
				Year 2	Year 3
Hot plate	Stirring during synthesis	5	400.000	2.000.000	2.000.000
Glass	Labwork	1 pack	2.000.000	2.000.000	2.000.000
Rent vacuum pump and muffle furnace	Filtering and heating process	1	3.000.000	3.000.000	3.000.000
Rent sonication bath	Sensitizationn process	1	1.000.000	1.000.000	1.000.000
Pressing equipment	Solar Cell Construction	1	5.000.000	5.000.000	5.000.000
Multimeter digital	Measure current and resistance	1	1.000.000	1.000.000	1.000.000
Solar Cell testing	Mengukur efisiensi sel	1	5.000.000	5.000.000	5.000.000
UV-Vis DR	Absorbtion analysis	50	100.000	1.200.000	
Voltametric cyclic	Voltammetry analysis	20	80.000	1.600.000	
SEM/EDX	Microstructur analysis	10	500.000	5.000.000	
XRD	Crystal structure analysis	20	200.000	4.000.000	
IPCE	Solar Cell testing	6	400.000	2.400.000	4.800.000
I-V Kethley Instrumen	Solar Cell testing	20	200.000	4.000.000	6.000.000
			SUBTOTAL (Rp)	37.200.000	29.800.000
3. Materials					
Material	Usage Justification	Quantity	Unit Price (Rp)	Per year budget (Rp)	
				Year 2	Year 3
Titanium Isopropox	Precursor Ti	2x500 mL	3.800.000	7.600.000	7.600.000
Dodecylamine	N source and pore template	2x 100 mL	1.100.000	2.200.000	
Deionized akuades	Solvent	100 L	600.000	600.000	600.000
Isopropanol GR	Solvent	2500 mL	1.260.000	1.260.000	1.260.000
Asetonitril (CH_3CN)	Thin film synthesis	250 mL	1.300.000	1.300.000	
Absolute Ethanol	Solvent	2500 mL	1.550.000	1.550.000	1.550.000
NaSe	Se precursor	100 gr	1.700.000	1.700.000	
TEA	Complexing agent	250 gram	820.000	820.000	820.000

Filter paper whatman	Filtering material	2 pak	330.000	660.000	660.000
Triton X	Thin film preparation	100 gram	1.400.000	1.400.000	2.800.000
Natrium selenosulfat	Prekursor Se	100 gram	1.940.000	1.940.000	1.940.000
Zinc Nitrate	Zn precursor	100 gram	1.720.000	720.000	
Porpyrine	Senisiteser	100 gram	1.240.000	1.240.000	1.240.000
Spiro-OMeTAD	Electrolyte	100 mL	1.920.000	1.920.000	3.940.000
N719	Complex sensitizer	1 gr	8.600.000	8.600.000	8.600.000
counter electrode Pt	Counter electrode	1 pak	2.600.000	2.600.000	5.200.000
ITO	Conductif substrat	2 pak	2.500.000	5.000.000	5.000.000
Termoplastik sealent	Sealent	1 pak	1.800.000	1.800.000	3.600.000
Binel aluminium	Hole cover	1 lembar	900.000	900.000	900.000
Asetone technic	Glass cleaning	2x500 mL	250.000	250.000	250.000
			SUBTOTAL (Rp)	48.560.000	52.830.000

4. Transportation

Rute (return)	Usage justification	Quantity	Unit Price (Rp)	Per year budget (Rp)	
				Year 2	Year 3
Yogya-Solo pp	IPCE and IV analysis	4	250.000	1.000.000	1.000.000
Yogya-Bandung pp	SEM analysis	1	1.200.000	1.200.000	
Yogya-Guangzhou pp	Joint research	2	10.000.000	20.000.000	20.000.000
Guangzhou-Yogya pp	Guest Professor	1	15.000.000	15.000.000	15.000.000
Conference evaluation		2	1.000.000	2.000.000	2.000.000
			SUBTOTAL (Rp)	39.200.000	38.000.000

5. Others

Activity	Activity justification	Quantity	Unit Price (Rp)	Per year budget (Rp)	
				Year 2	Year 3
Administration	ATK	1	1.000.000	1.000.000	1.000.000
Publication	Article and submit	2	3.000.000	6.000.000	8.000.000
International conference	Publication	1	10.000.000	10.000.000	10.000.000
Seminar instrument, monev and result	LPPM	1	3.000.000	3.000.000	3.000.000
Literature searching ang fotocopy	Literature	1	500.000	500.000	500.000
Guest professor accommodation	Accommodation guest lecturer	1	5.000.000	5.000.000	5.000.000
Reporting	Progress and final report	1	2.000.000	2.000.000	2.000.000
Dokumentation	Research documentation	1	1.000.000	1.000.000	1.000.000
			SUBTOTAL (Rp)	27.000.000	29.500.000
			TOTAL BUDGET PER YEAR TAHUN (Rp)	198.160.000	198.330.000
			TOTAL BUDGET FOR ALL YEAR (Rp)	**591.360.000**	

Attachment 2

EQUIPMENTS FACILITY

(1). Laboratory

This research will be done at Inorganic Chemistry Laboratory of Universitas Negeri Yogyakarta and School of Chemistry and Engineering, Sun Yat-sen University

(2). Main Instruments

Main instruments that will be use in this research are:

No	Nama Alat	Spesifikasi Alat	Tempat	Kegunaan
1	XRD	Rigaku	FMIPA UNY	Crystal Structure Analysis
2	UV Vis/DR	Perkin Elmer	FMIPA UNY	Solid state absorbance analysis
3	Cyclic Voltammetry		FMIPA UNY	Voltametric Analyisis
4	SEM/EDX		BLPG Bandung	Microstructure analysis
5	I-V dan IPCE Measurement	Kethley	Sun Yat sen University	Solar Cell analysis
6	XPS	Thermoadvance	Sun Yat-sen University	Solar Cell analysis

Attachment 3

ORGANIZATION STRUCTURE RESEARCH TEAM

No	Name/NIP	Position in the Research	Time Alocation (Hour/Week)	Job Description
1	Dr Cahyorini K, M.Si/ 197707232003122001	Chief	20	-Research coordination - responsible for all research activities - N-TiO_2 modification and characterization -solar cell construction and testing
2	Prof. KH Sugiyarto/ 19480915 196806 1 001	Member	15	-N-TiO_2 sensitization -optimization of N-TiO_2 sensitization -solar cell construction and testing

LETTER OF AGREEMENT FOR JOINT RESEARCH

The Faculty Mathematics and natural Sciences, **Yogyakarta State University** (YSU), a Government University at Yogyakarta, Indonesia and the School of Chemistry and Chemical Engineering, **Sun Yat-sen University**, Guangzhou, China wish to enter into an investigation, or Joint Collaborative Research on **Material for Solar Cell Application**. The Principal Investigators are **Dr Cahyorini Kusumawardani** at YSU and **Prof Mingmei Wu** at Sun Yat-sen University who jointly are responsible for the direction and conduct of the JOINT Research. This letter of agreement consist:

1. **Research Project.** Efforts will be made to synthesize semiconductor materials and its application on solar cells system. These investigations will utilize various lab procedures. Both researchers shall provide a mutually agreed upon number of compounds and knowledges, and communicate with each other on a frequent and informal basis as agreed upon between these PRINCIPAL INVESTIGATORS.
2. **Term of the Joint Research.** The JOINT RESEARCH will be carried out during the period years 2013-2015. Either party may terminate the JOINT STUDY by giving the other party thirty (30) days written notice.
3. **Budget and Funding.** Each party will bear all of its own costs and expenses in connection with the Research Project. Each party will responsible with the expense of research done at their institution including chemicals, laboratory facilities and instrumentations.
4. **Results of Research Project.** Each party will keep the other parties informed of research results obtained from its work in connection with the Joint research. Following the collaboration, each party shall have an unrestricted right to use for its own internal research purposes all research results, obtained from the Research Project. For patentable research, inventorship of inventions will be determined in accordance with principles of patent law. Both parties may pursue joint patent protection of Joint Inventions.
5. **Publications.** The parties agree that it is part of each party's function to disseminate information and to make the information available for research. The parties will cooperate in appropriate publication of the results of the JOINT RESEARCH. The authorship for any paper is determined by accepted scientific practice.
6. **Responsibilities of the Parties.** Each party is an independent contractor and has no authority to bind or act on behalf of another party. Each party is responsible and liable to the other parties only for its own acts and omissions, relating to the Joint Research Project or to any Research Materials that have been transferred to it in connection with the Joint Research Project.
7. **Compliance with Laws and Regulations.** All research done in connection with the Joint Research, including all use of Research Materials transferred hereunder, will be done in compliance with all governmental regulations and guidelines of the Indonesian and China.

The parties have caused this AGREEMENT to be executed by their duly authorized representatives.

FACULTY MATHEMATICS AND NATURAL SCIENCES, YOGYAKARTA STATE UNIVERSITY

By : ________________ Date : 12 April 2013
Name : Dr Hartono
Title : Dean

SCHOOL OF CHEMISTRY AND CHEMICAL ENGINEERING, SUN YAT-SEN UNIVERSITY

By : ________________ Date : 13 April 2013
Name : Prof Mao Zong-Wan
Title : Dean

Read and acknowledged:

: ________________ .
Dr Cahyorini Kusumawardani
Date: 12 April 2013

____
Prof. Mingmei Wu
Date: 13 April 2013

School of Chemistry and Chemical Engineering
Sun Yat-sen University

School of Chemistry and Chemical Engineering
April 2013

Dr Cahyorini Kusumawardani
Chemistry Department – Yogyakarta State University
Yogyakarta, 55281
INDONESIA

Dear Dr Cahyorini,

This letter is to advise that you will be hosted at School of Chemistry, Sun Yat-sen University for the duration of your joint project with Prof. Ming Mei-Wu in solid state dye-sensitized solar cells. The duration of the project will be 2013-2015.

We have agreed to provide chemicals, instrumentations, and accommodation during your stay in Sun Yat-sen University.

The program of research that you proposed has been accepted by this faculty and involves:

- Surface characterization (eg. XPS and AFM)
- Detailed material characterization (eg. SEM and TEM)
- Trial for solar cell testing (assembling and IV measurement)
- Data analysis and reporting

I am looking forward to seeing you in Guangzhou and I express the congratulations of our Faculty on your achievement.

Sincerely yours,
Prof Mao Zong-wan
Dean

Attachment 4 Curriculum Vitae

CURRICULUM VITAE OF CHIEF PROJECT

A. Identitas Diri

1	Nama Lengkap	Dr. Cahyorini Kusumawardani, M.Si
2	Jenis Kelamin	P
3	Jabatan Fungsional	Lektor
4	NIP	19770723 200312 2 001
5	NIDN	0023077704
6	Tempat dan Tanggal Lahir	Bojonegoro, 23 Juli 1977
7	Email	cahyorini.k@uny.ac.id
8	Nomor Telepon/Faks/HP	0274798623/0818467905
9	Alamat Kantor	Karangmalang, Yogyakarta, 55281
10	Nomor Telepon/Faks	(0274) 586168/(0274) 548203
11	Lulusan yang Telah Dihasilkan	S-1 = 19 orang; S-2= - ; S-3= -
13	Mata Kuliah yang diampu	1. Kimia Anorganik
		2. Kimia Komputasi
		3. Praktikum Kimia Anorganik

B. Riwayat Pendidikan

	S-1	S-2	S-3
Nama Perguruan Tinggi	Universitas Gadjah Mada	Universitas Gadjah Mada	Universitas Gadjah Mada
Bidang Ilmu	Kimia	Ilmu Kimia	Ilmu Kimia
Tahun Masuk-Lulus	1995-1999	2000-2002	2007-2012
Judul Skripsi/Thesis	Modifikasi Ukuran Rongga Zeolit A menggunakan Templat Organik	Simulasi Monte Carlo Ion Co^{2+} dalam Amoniak Cair	Sintesis Sol Gel TiO_2 Berdoping Nitrogen dan Preparasi *In Situ* Kompleks Rutenium pada TiO_2 Berdoping Nitrogen
Nama Pembimbing/Promotor	Prof Dr AH Bambang Setiadji	Prof. Dr. Harno Dwi Pranowo	Prof Narsito

C. Pengalaman Penelitian Dalam 5 tahun Terakhir

No.	**Tahun**	**Judul penelitian**	**Pendanaan**	
			Sumber	Jml (juta Rp)
1.	2011	Pengembangan Elektroda Nanostruktur Anorganik untuk Aplikasi Sel Surya Hybrid sebagai Alternatif Sumber Energi Terbarukan	Stranas Th ke2	90
2	2010	Pengembangan Elektroda Nanostruktur Anorganik untuk Aplikasi Sel Surya Hybrid sebagai Alternatif Sumber Energi Terbarukan	Stranas Th ke1	86
3	2009	Pengembangan DSSC Efisiensi Tinggi berbasis TiO_2 Terdoping Nitrogen	Stranas Th ke1	92
4	2009	Sensitisasi TiO_2 terdoping Nitrogen melalui pembentukan *in situ* Kompleks Rutenium untuk Aplikasi *Dye-sensitised Solar Cells*	Hibah Doktor, Dikti	47,5
5	2008	Sintesis dan Karakterisasi Nanokristal TiO_2 terdoping Nitrogen untuk aplikasi Fotokatalis Reaksi Degradasi Senyawa Organik	Hibah Bersaing, Dikti	40
6	2007-2008	Pengembangan Sel Surya Berbasis Material Nanokristal TiO_2 dengan Kompleks Logam sebagai Sensitiser	Hibah Pascasarjana	172
7	2007	Metode *Combined Quantum Mechanical-Molecular Mechanical* (QM/MM) untuk Menentukan Struktur dan Dinamika Solvasi Ion Ru^{2+} dalam Air dan Amoniak Cair	Hibah Pekerti, DIKTI	67

D. Pengalaman Pengabdian Kepada Masyarakat dalam 5 Tahun Terakhir

No.	Tahun	Judul Pengabdian Kepada Masyarakat	Pendanaan	
			Sumber*	Jml (juta Rp)
1	2009	Pengembangan Produk Olahan Jagung untuk Meningkatkan Kesejahteraan Pesisir Pantai Selatan Kecamatan Ambal Kabupaten Kebumen	Dana Mandiri	7,5

E. Pengalaman Penulisan Artikel dalam Jurnal dalam 5 Tahun Terakhir

No	Judul Artikel	Jurnal	Volume/Nomor/ Tahun
1	Hybrid Solar Cells based on polivinil electrolyte	*International Journal of Photoenergy*	In press
1.	Synthesis of Visible Light Active N-doped Titania Photocatalyst	*Asian Journal of Chemistry*	24/1/2012
2.	Chemically Synthesized of N-	*Thammasat International Journal*	15/4/2010

	doped Titania and Its Photoapplication	*of Science and Technology*	
3.	Synthesis of Nanocrystalline of N-Doped TiO_2 and Its Application on High Efficiency of Dye-sensitised Solar Cells	*Science Journal of Ubon Ratchathani University*	7/1/2010
4.	Study of the Formation of Mesoporous TiO_2 using Isopropoxide Precursors under Less Water Conditions	*Indonesian Journal of Chemistry*	9/1/2009
5.	The Preferential Structure of Co^{2+} in Aqueous Solution Determined by Monte Carlo Simulation	*Indonesian Journal of Chemistry*	8/3/2008

F. Pengalaman Penyampaian makalah Secara Oral Pada Pertemuan/Seminar Ilmiah dalam 5 Tahun Terakhir

No.	Judul Pertemuan	Judul Artikel ilmiah	Waktu dan tempat
1	ICCE 2012	Hydrothermal Synthesis of Nitrogen-doped TiO_2 for Dye Degradation Photocatalityc Reaction	2012, Jeju Island, Korea Selatan
1	14^{th} Asian Chemical Congress	Development of Dye-Sensitized Solar Cells based on TiO_2 Prepared through One Step Sol Gel Synthesis	2011, Bangkok, Thailand
2	The Saudi International Conference on Photonic and Optoelectronic Conference	Dye-sensitized Solar Cells based on *In Situ* Sensitized of Nitrogen Doped TiO_2	2011, Riyadh, Saudi Arabia
3	6^{th} Jordanian International Conference of Chemistry,	Synthesis and Characterization of High Surface Area Nitrogen Doped Titania Mesopore for Visible Light Photocatalyst	2011, Yarmouk University, Jordan
4	Pure and Applied Chemistry Conference	Surface Modification of TiO_2 with PbS nanoparticle for DSSC application	2010, Ubon Ratchatani, Thailand
5	Chemical, Biological and Environmental Engineering	Synthesis Of Visible Light Active N-Doped Titania Photocatalyst	2009, Singapura
6	Pure and Applied Chemistry Conference	Synthesis and Characterization of Zn/Al Hydrotalcites through High Supersaturation Co-Precipitation	2009, Phitsanulok, Thailand
7	Internasional Conference	Synthesis Of Anatase-Type Nitrogen-Doped	2008, Penang,

	for Young Chemist, School of Chemical Science	Titania Mesopore Through Sol Gel Method	Malaysia

G. Pengalaman penulisan Buku dalam 5 Tahun Terakhir

No	Judul Buku	Tahun	Jumlah Halaman	Penerbit
1	-	-	-	-

H. Pengalaman Perolehan HKI dalam 5 Tahun Terakhir

No	Judul/Tema HKI	Tahun	Jenis	Nomor P/ID
-	-	-		

I. Pengalaman Merumuskan Kebijakan Publik/Rekayasa social Lainnya Dalam 5 Tahun Terakhir

No	Judul/Tema/Jenis Rekayasa Sosial lainnya yang Telah Diterapkan	Tahun	Tempat Penerapan	Respons Masyarakat
-	-	-	-	-

J. Penghargaan yang Pernah Diraih dalam 10 Tahun Terakhir (dari pemerintah, asosiasi atau institusi lainnya)

No	Jenis Penghargaan	Institusi Pemberi Penghargaan	Tahun
-	-	-	-

Semua data yang saya isikan dan tercantum dalam biodata ini adalah benar dan dapat dipertanggungjawabkan secara hukum. Apabila di kemudian hari ternyata dijumpai ketidaksesuaian dengan kenyataan saya sanggupmenerima resikonya.

Demikian biodata ini saya buat dengan sebenarnya untuk memenuhi salah satu persyaratan dalam pengajuan Penelitian Kerjasama Internasional

Yogyakarta, 12 April 2013

METERAI TEMPEL
71547ABF417912347
ENAM RIBU RUPIAH 6000

Dr Cahyorini Kusumawardani

CURRICULUM VITAE OF RESEARCH MEMBER

A. Identitas Diri

1	Nama Lengkap	Prof. Drs. Kristian Handoyo Sugiyarto, M.Sc., Ph.D.
2	Jenis Kelamin	L
3	Jabatan Fungsional	Guru Besar
4	NIP	19480915 196806 1 001
5	NIDN	0015094803
6	Tempat dan Tanggal Lahir	Sukoharjo, 15 September 1948
7	Email	kristiansugiyarto@yahoo.com
8	Nomor Telepon/HP	08157935534
9	Alamat Kantor	Karangmalang, Yogyakarta, 55281
10	Nomor Telepon/Faks	(0274) 586168/(0274) 548203
11	Lulusan yang Telah dihasilkan	S-1 > 50 orang; S-2= 15 ; S-3= 5
12	Mata Kuliah yang diampu	4. Kimia Anorganik I-IV
		5. Bioanorganik
		6. Praktikum Kimia Organik
		7. Prinsip dan Teori Spektroskopi
		8. Bahasa Inggris
		9. Kewarganegaraan

B. Riwayat Pendidikan

	S-1	S-2	S-3
Nama Perguruan Tinggi	Universitas Negeri Yogyakarta	University of New South Wales	University of New South Wales
Bidang Ilmu	Pendidikan Kimia	Inorganic Chemistry	Inorganic Chemistry
Tahun Masuk-Lulus	1972-1978	1985-1987	1992-1995
Judul Skripsi/Thesis/Disertasi	Studi Komparasi Hasil Belajar Ilmu Kimia di Kelas 1 Semester II SMA Negeri Surakarta dengan Sistem Modal dan dengan Sistem Tradisional	Electronic Properties of Metal Derivatives of Chelates Containing Five-Membered Heterocycles	Electronic Properties of Iron (II) Complexes of 1,2,3-triazole and Related Multidentates
Nama Pembimbing/Promotor	Drs Sukardjo	Prof H.A. Goodwin	Prof H.A. Goodwin

C. Pengalaman Penelitian Dalam 5 tahun Terakhir

No.	Tahun	Judul penelitian	Pendanaan	
			Sumber	Jml (juta Rp)
1	2011	Palladium(II) complexes of imidazolin-2-ylidene N-heterocyclic carbene ligands with redox-	Program PAR DIKTI	150

		active dimethoxyphenyl or (hydro)quinonyl substituents		
2	2010	Miskonsepsi dalam Pokok Bahasan Bilangan Kuantum dan Konfigurasi Elektronik pada Berbagai Buku-Ajar Kimia SMA dan Para Guru Penggunanya, 2010	DIPA UNY	10
3	2009-2010	Lesson Study Peningkatan Kualitas Pembelajaran Kimia Anorganik I melalui Cooperative Learning	DIPA UNY	60
4	2009	Efektivitas Multimedia dan Model Kemas-Rapat Geometri untuk Mengatasi Miskonsepsi pada Pembelajaran Terintegrasi Kimia Anorganik	DIPA UNY	25
5	2008	Implementasi Cooperative Learning Tipe Jigsaw pada Pembelajaran Kimia Anorganik I	Hibah Pengajaran A2	30
6	2006	Structural Study on Solution-State Spin-Equilibrium of Metal Complexes	JICA	12.000 US$

D. Pengalaman Pengabdian Kepada Masyarakat dalam 5 Tahun Terakhir

No.	Tahun	Judul Pengabdian Kepada Masyarakat	Pendanaan	
			Sumber*	Jml (juta Rp)
1	2003-sekarang	Pembinaan Olimpiade Kimia Tingkat Provinsi DIY	Dinas Pendidikan Prop DIY	
2	2007-2010	Pembinaan RSBI SMA Kasihan 1, Bantul	Dinas Pendidikan Prop DIY	

E. Pengalaman Penulisan Artikel dalam Jurnal dalam 5 Tahun Terakhir

No.	Judul Artikel Ilmiah	Nama jurnal	Volume/Nomor/ Tahun
1	Palladium(II) complexes of imidazolin-2-ylidene N-heterocyclic carbene ligands with redox-active dimethoxyphenyl or (hydro)quinonyl substituents	*Inorganic Chimica Acta*	3/370/2011
2	Structural Study on Solution-State Spin-Equilibrium of Metal Complexes	*Ritsumeikan*	8/5/2007

F. Pengalaman Penyampaian makalah Secara Oral Pada Pertemuan/Seminar Ilmiah dalam 5 Tahun Terakhir

	Pertemuan		
-	-	-	-

G. Pengalaman penulisan Buku dalam 5 Tahun Terakhir

No	Judul Buku	Tahun	Jumlah Halaman	Penerbit
1	Dasar-dasar Kimia Anorganik Transisi	2012	260	Graha Ilmu
2	Kimia Anorganik Logam	2010	215	Graha Ilmu
3	Kimia Anorganik III	2009	225	UNY Press

H. Pengalaman Perolehan HKI dalam 5 Tahun Terakhir

No	Judul/Tema HKI	Tahun	Jenis	Nomor P/ID
-	-	-	-	-

I. Pengalaman Merumuskan Kebijakan Publik/Rekayasa social Lainnya Dalam 5 Tahun Terakhir

No	Judul/Tema/Jenis Rekayasa Sosial lainnya yang Telah Diterapkan	Tahun	Tempat Penerapan	Respons Masyarakat
-	-	-	-	-

J. Penghargaan yang Pernah Diraih dalam 10 Tahun Terakhir (dari pemerintah, asosiasi atau institusi lainnya)

No	Jenis Penghargaan	Institusi Pemberi Penghargaan	Tahun
-	-	-	-

Semua data yang saya isikan dan tercantum dalam biodata ini adalah benar dan dapat dipertanggungjawabkan secara hukum. Apabila di kemudian hari ternyata dijumpai ketidaksesuaian dengan kenyataan saya sanggupmenerima resikonya.
Demikian biodata ini saya buat dengan sebenarnya untuk memenuhi salah satu persyaratan dalam pengajuan Penelitian Kerjasama Internasional.

Yogyakarta, 15 April 2013
Pengusul

METERAI TEMPEL
A7EDDABF417912
ENAM RIBU RUPIAH
6000

Prof. KH Sugiyarto, Ph.D

Attachment 5. Statement Letter

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN
UNIVERSITAS NEGERI YOGYAKARTA
LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT
Alamat: Karangmalang, Yogyakarta. 55281.
Telp. (0274) 550839 Fax. (0274) 518617. e-mail: lppm.uny@gmail.com

STATEMENT LETTER

Hereby, I am the person who sign the letter below:

Name	: Dr Cahyorini Kusumawardani
NIP	: 197707232003122001
Pangkat/Golongan	: Penata/IIIc
Address	: Perumahan Sidoarum Blok II Jl Nangka No 60, Sleman, Yogyakarta

have state that our proposal entitled "Development of Solid State Dye-sensitized Solar Cells based on Nitrogen-doped TiO_2" that proposed on International Collaboration Research scheme at the Fiscal Year 2014 is **original and has never been funded by another institution/funding source.**

When later found discrepancies with this statement, then I am willing charged and processed in accordance with applicable regulations and restore the entire cost of the research that has been received into the state treasury.

This statement was made with actual and with truth.

Yogyakarta, 29 Mei 2013

Acknowledged by,
Ketua LPPM UNY

(Prof. Anik Ghufron, M.Pd)
NIP 196211111988031001

Stated and signed by,

METERAI TEMPEL
C0C8CABF4185304
ENAM RIBU RUPIAH
6000 DJP

Dr Cahyorini Kusumawardani
NIP 197707232003122001