ECTI-CON 20

CONFERENCE

ECTI Association

May 10-13, 2006

Ubonburi Hotel, Ubon Ratchathani, THAILAND

ECTI Association · IEEE-LEOS Thailand Chapter · IEEE MTT/AP/ED Thailand Chapter · NECTEC · Seagate · IEEE CAS Society · IEEE LEOS

ECTI-CON 2006

Proceedings of the 2006 Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI) International Conference

Wednesday May 10 – Saturday May 13, 2006

Ubonburi Hotel, Ubon Ratchathani, THAILAND

Organized by

Electrical Engineering/Electronics, Computer, Telecommunications, and Information Technology (ECTI) Association

ECTI-CON 2006

Proceedings of the 2006 Electrical Engineering/ Electronics, Computer, Telecommunications and Information Technology (ECTI) International Conference

Wednesday May 10 – Saturday May 13, 2006

Ubonburi Hotel, Ubon Ratchathani, THAILAND

Organized by

Electrical Engineering/Electronics, Computer, Telecommunications, and Information Technology (ECTI) Association

---

Steering Committee

Pansak Siriruchatapong (NECTEC), Chair
Wanlop Surakampontorn (KMITL)
Sawasd Tantaratana (SIIT)
Sawat Tantiphanwadi (NSTDA)
Akachai Sang-in (CMU)
Sinchai Kamolphiwong (PSU)
Weerapant Musigasarn (PSU)
Chidchanok Lursinsap (CU)
Kobchai Dejhan (KMITL)
Somchai Chatratana (KMITNB)
Somsak Choomchuay (KMITL), Secretary

International Advisory Committee

Akinori Nishihara, (Tokyo Tech., Japan)
Hara Shinji (U. of Tokyo, Japan)
Luigi Benedicenti, (U. of Regina, Canada)
Rolf H. Jansen (Aachen U., Germany)
Yong-Hwan Lee (SNU, Korea)
Narong Yoothanom (SPU)

Organizing Committee

General Chair
Wanlop Surakampontorn (KMITL)

Vice chairs
Monai Krairiksh (KMITL)

International coordination chair
Saykhong Saynasine (NUOL,Laos)
Hang Chan (RUPP,Cambodia)
Nicholas Shuley (UQ,Australia)
Pung Keng (NUS,Singapore)

Technical Program Co-Chairs
Athikom Roeksabutr (MUT)
Chaiwut Chat-uthai (KMITL)
Bundit Thipakorn (KMUTT)
Jun-ichi Takada (TIT,Japan)
Prabhas Chongsatitwattana (CU)
Vutipong Areekul (KU)
Waree Kongprawechnon (SIIT)
Jitkasem Ngamnil (MUT)

Special Session Chairs
Kazushi Nakano (UEC,Japan)
Prayoot Akkaraekthalin (KMITNB)
Chuwong Phongcharoenpanich (KMITL)

Local Arrangement Chairs
Werachet Khan-ngenn (KMITL)
Mongkol Pasuyatanont (UBU)
Rungrangsee Vibulchai (UNC)
Surajate On-rit (UBRU)
Apirat Siritaratiwai (KKU)
Phaophak Sirisuk (MUT)
Yingrak Auttawaitkul (RTU)
Prasit Surasil (UVC)

Publication Chairs
Apirat Siritaratiwai (KKU)
Raungrong Suleesathira (KMUTT)
Danai Torrungrueng (AUST)

Publicity Chairs
Pinit Kumhom (KMUTT)
Anantawat Kunakorn (KMITL)

Exhibition Chair
Keattisak Sripimanwat (NECTEC)
Sdhabhon Bhokha (UBU)
Petmanee Viriyasudphong (UNC)
Supachate Innet (UTCC)
Denchai Worasawate (KU)
Supaporn Buphaprohm (UVC)

Finance Chairs
Banlue Srisuchinwong (SIIT)
Vutipong Areekul (KU)

General Secretary
Chalie Charoenlarpnopparut (SIIT)
Apinunt Thanachayanont (KMITL)

Co-Sponsored by
National Electronics and Computer Technology Center (NECTEC)
National Science and Technology Development Agency (NSTDA)

Technical collaboration with
IEEE Communications Society, Thailand Chapter
IEEE Circuits and Systems Society, Thailand Chapter
IEEE MTT/AP/ED, Thailand Chapter
IEEE Laser and Electro-Optics Society, Thailand Chapter

Table of Contents

Message

from

Chairman of Steering Committee

The third ECTI-CON is organized as international conference at Ubonburi Hotel in Ubon Ratchathani province Thailand on May 10-13, 2006. The steering committee of ECTI-CON has determined Ubon Ratchathani province as the venue for the third ECTI-CON in the beginning of 2005, since we have a policy to expand opportunity for researchers not only in nationwide of Thailand, but also neighboring countries in Indo-China region such as Cambodia, Laos, and Vietnam.

Ubon Ratchathani is an ancient town with 4,000 year-old culture located on the Maekhong river bank in the center of triangle among Laos, Cambodia, and Thailand. It has the biggest population and area in the south of north eastern part of Thailand, and can be counted as center of this region. This is the main reason that the committee decided to move venue to this province in 2006. Hopefully, the third ECTI-CON 2006 works as research gateway to this region, and many researchers in this region become more active, especially in the ECTI-CON in the future.

In the next ECTI-CON in 2007, the steering committee has a concept to move the venue back to the center of Thailand nearby Bangkok, and go to remote region again in 2008.

On behalf of the steering committee of ECTI-CON, I would like to show my appreciations against the excellent organizing works performed by all of ECTI-CON 2006 organizing committee members and staff, and also excellent research results presented by researchers around the world. Hopefully, the participants of ECTI-CON 2006 will enjoy presentation, discussion, banquet, local food, local culture, and tour. Finally, I look forward to meeting you again at the ECTI-CON 2007 next year.

Pansak siriruchatapong
Chairman of ECTI-CON Steering Committee

Message

from

General Committee Chair

It is indeed my great honor to cordially welcome all the participants to the 2006 Electrical/Electronics, Computer, Telecommunications, and Information Technology Conference (ECTI 2006), held on May 10-13 2006, in Ubonburi Hotel and Resort, Ubon Ratchathani province, Thailand. This is the third annual conference in the series, where the first ECTI Conf kicks off in the year 2004 as one of the major activities of the ECTI Association. It should be noticed that this is the first time that we extend the conference to the place that is not in the popular places like Pataya, Chaingmai and Phuket. However, we still got a very good response.

The objective of the conference is to annually bring together researchers from Thailand as well as other parts of the world to discuss and exchange experiences with the aim to stimulate and enhance the research and development in the areas that are related to Electrical/Electronics, Communications and Information Technologies. It is also to provide a forum for the discussion of original works, new ideas and new recent advances in the areas.

In the capacity of the Organizing Committee Chair, I would like to express sincere appreciation to the significant contributions and efforts by organizing committee members, especially the General Secretary: Assoc. Prof. Dr. Kosin Chamnongthai, the Technical Program Chair: Assoc Prof. Dr. Athikom Roeksabutr and the Local Arrangement Chair, Assoc. Prof. Dr. Werachet Khan-ngenn, which make this conference a great success. In addition, the valuable contributions from the authors that submitted technical papers for review, attendees, technical program committee members, speakers, and session chairs are gratefully acknowledged. We do hope that, you participate in the conference with pleasure and find a good opportunity to meet, to exchange ideas and to make research contacts and collaboration.

Wanlop Surakampontorn
General Committee Chair ECTI-CON 2006

Message

from

Technical Program Chair

Welcome to ECTI-CON 2006 - the third annual international conference organized by Electrical Engineering/Electronics, Computer, Telecommunications and Information (ECTI) Technology association of Thailand. This happens to be the first international conference in Ubon Ratchathani Province, an ancient town with 4000 year old culture on the Maekhong river bank.

This year conference offers an outstanding program in 47 sessions for about 192 contributed papers, being accepted from 230 submitted papers from more 8 countries. The reviewers, who are the experts in the particular fields, were working very hard in voluntary to select those quality contributed papers. In addition, 28 invited papers are also included in special sessions, whose area is currently in the hot issue.

"**Technology for Life**" is the theme for ECTI-CON 2006. I believe that you will find it true after attending technical sessions through the conference.

All keynote speakers have been honorably invited to give speech on the topics that should encourage research community in Thailand as well as illustrate the research scenery of Thai neighbors.

I would like to thank keynote speakers, and all the technical program committee members and chairs who voluntarily invest their own time inviting speakers, selecting papers, and arranging such the impressive conference. Of course, sincere thanks must finally go to all authors, without whom the conference would not occur, who make contribution of their papers to the conference.

Thank for your participation in ECTI-CON 2006. I strongly believe this is a good opportunity to share knowledge and experiences among participants. Please have a great time and use this opportunity to meet more people and make yourself known by exchanging experiences and both technical and non-technical information.

Athikom Roeksabutr
Technical Program Chair of ECTI-CON 2006

List of Reviewers

We would like to express special thanks to the following individual and anonymous reviewers for their effort in the review process of ECTI-CON 2006:

Akinori Nishihara
Amorntep Jirattitichareon
Anantawat Kunakorn
Andrew Davison
Anuwat Jangwanitlert
Apichai Bhatranand
Apichan Kanjanavapastit
Apinunt Thanachayanont
Apirat Siritaratiwat
Apisak Worapishet
Athikom Roeksabutr
Atsushi Takahashi
Bongkarn Homnan
Boonserm Kijsirikul
Bundhit Eua-arporn
Bundit Thipakorn
Chaiwut Chat-Uthai
Chalie Charoenlarpnopparut
Chanchai Laohapengsang
Chanin Bunlaksananusorn
Chanjira Sinthanayothin
Chaodit Aswakul
Chiranut Sa-ngiamsak
Chokchai Sangdao
Chutham Sawigun
Chuwong Phongcharoenpanich
Danai Torrungrueng
Daranee Hormdee
David Banjerdpongchai
Denchai Worasawate
Ekachai Leelarasmee
Hiroshi Tamura
Issarachai Ngamroo
Itsda Boonyaroonate
Jatuporn Chinrungrueng
Jitkasame Ngarmnil
Jun-ichi Takada
Kasin Vichienchom
Kazushi Nakano
Kitti Attakitmongcol
Kittipong Tonmitr
Kohji Higuchi
Komsak Meksamoot
Kosin Chamnongthai
Kriangkrai Sooksood
Lunchakorn Wuttisittikulkij
Mitchai Chongcheawchamnan
Monai Krairiksh
Namkhun Srisanit
Narumol Kiatwarin
Nimit Chomnawang
Nipapon Siripon
Nipon Theera-Umpon
Nongluk Covavisaruch
Nontawat Chuladaycha
Pakorn Kaewtrakulpong
Panumas Khumsat
Panuthat Boonpramuk
Parnjit Damrongkulkamjorn
Pathomthat Chiradeja
Peerapol Yuvapoositanon
Peng Hin Lee
Phakphoom Boonyanant
Phaophak Sirisuk
Pichai Aree
Pinit Thepsatorn
Piyasawat Navaratana Na Ayudhy
Prabhas Chongsatitwattana
Prajuab Pawarangkoon
Prawit Chumchu
Prayoot Akkaraekthalin
Saliltip Sinthusonthishat
Sanpachai Huvanandana
Sansanee Auephanwiriyakul
Santi Asawasripongtorn
Sanya Mitaim
Sawasd Tantaratana
Sawat Tantiphanwadi
Siripun Thongchai
Siriroj Sirisukprasert
Somboon Sangwongwanich
Somchat Jiriwibhakorn
Sompob Polmai
Somporn Sirisumrannukul
Somying Thainimit
Songsak Chusanapipat
Stanislav Makhanov
Surapan Airphaiboon
Tanee Demeechai
Tawan Phurat
Taweedej Sirithanapipat
Taworn B
Techaumnat Boonchai
Teerasit Kasetkasem
Thanatchai Kulworawanichpong
Thawatchai Meeteevarunyoo
Thumrongrat Amornraksa
Tiparatana Wongcharoen
Toshiaki Kondo
Toshihisa Tanaka
Varakorn Kasemsuwan
Vutipong Areekul
Wanlop Surakampontorn
Warakorn Charoensuk
Waree Kongprawechnon
Wichian Chutimaskul
Worapong Tangsrirat
Yongyuth Permpoontanalarp
Yoshikazu Miyanaga

Photoinduced on laterally spreading of space-charge-region in planar metal-semiconductor-metal structures

S.Khunkhao [a] **S. Niemcharoen** [b] **M. Duangsang** [b] **K.Sato** [c]

[a] Department of Electrical Engineering, Faculty of Engineering, Sripatum University, 61 Phahonyothin Road, Jatujak, Bangkhane, Bangkok, 10900 Thailand. Email:sanya@spu.ac.th

[b] Electronics Research Center, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Charongkrung Road, Ladkrabang, Bangkok, 10520 Thailand.Email: knsurasa@kmitl.ac.th

[c] Department of Electronics, School of Information Technology and Electronics, Tokai University, Kitakaname 1117, Hiratsuka, Kanagawa, 259-1292 Japan. Email:kznrsato@keyaki.cc.u-tokai.ac.jp

ABSTRACT

Photoinduced on lateral spreading along the surface of space-charge-region (SCR) of planar metal-semiconductor-metal (MSM) structures have been investigated. This purpose for the SCR of such a structure plays a key role in generating photocurrent and thus, in dc and/or ac scheme, the wider SCR along the active surface is the better from the efficiency point of view. To study the SCR along the surface of MSM structures, we prepared planar MSM structures leaving the undepleted region between the electrodes. We examined their SCR spreading through the photocurrent-bias voltage characteristics. The experimental results were compared with the numerical simulation using a quasi -1D model of such a planar structure. Since the depleted region along the surface would be much more sensitive to the incident illumination than the undepleted region, increase in bias causes the increase in the depletion width and thus detected photocurrent.

Keywords: Planar metal-semiconductor-metal structure; Optical sensor; Space-charge-region; Photodetector; Electronic iris.

1. INTRODUCTION

The MSM-PD structure has Schottky-barriers on both sides and along neutral region between the barriers, where there must be the so-called space-charge region (SCR) contributing to the photocurrent generation [1]. To achieve an efficient photocurrent generation in the MSM structures, larger active area is desirable [2]. That is, the lateral spreading of the SCR would be one of the trade-off problems for MSM photodetector structures. As one of the solutions of this problem, an interdigitated MSM structure has been investigated intensively [3].

Preparing silicon-based planar MSM-PD structures leaving the undepleted region between the Schottky-barriers on both sides, their current-bias voltage relationships were mainly measured under different optical illumination levels. Based on the quasi-1D model for the active area of the present MSM-PD structure, numerical simulations were also carried out. Comparison between the experimental results and the simulations were presented.

2. EXPERIMENTALS

2.1 Sample preparation

N-type silicon (n-Si) wafers were utilized for preparing the samples in this work. The resistivity of the wafers is classified into three groups, (40-50)Ωcm mainly used, 23Ωcm and (9-12)Ωcm, where all of these values are quoted by the manufacturers. Immediately after chemically cleaning a wafer, it was set into the chamber for deposition of metal. As a barrier metal, molybdenum (Mo) was deposited by an electron-beam evaporator. The starting degree of vacuum for evaporation was $(0.8-1.0)\times10^{-4}$ Pa.

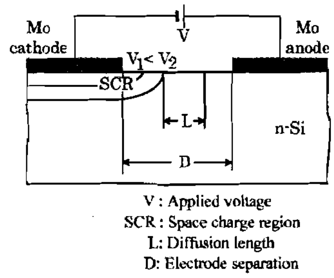


Fig.1: Cross-sectional view of an experimental planar MSM structure.

The thickness of the deposited film was approximately (1000-1200)Å. Employing standard photolithography and lift-off technique, the electrodes on both sides of the active area were formed, the size of which is $3\times3mm^2$ (single slit type). Mo serves as both barrier metal and electrodes. Shown in *Fig.1* is the cross-section of the samples. The samples having the electrode separation 20, 100, 500, 1000 and 2000µm were prepared. These values of the electrode separation are larger than the expected width of the SCR along the front surface, resulting in leaving the depleted region.

2.2 Measurement procedure

The current versus applied bias (I-V) characteristics were measured under optical illumination and in the dark conditions. To irradiate the samples a helium-neon (He-Ne) laser having the wavelength of 633nm or halogen lamp was used. The block diagram of the setup PC-controlled for measurements of I-V characteristics is shown in *Fig.2.* A neutral-density (ND) filter was used to control the intensity of illumination and thus the current level of the device under test. All measurements were carried out in the room temperatures. The increase in the dark current with applying bias might be attributed to the charge generation in the expanding SCR under reverse bias [7] and/or the incompleteness of fabrication process of the samples.

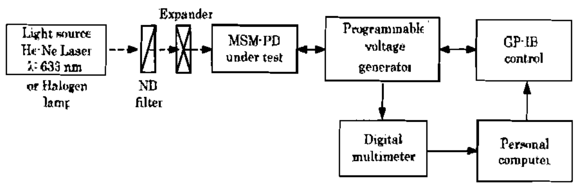
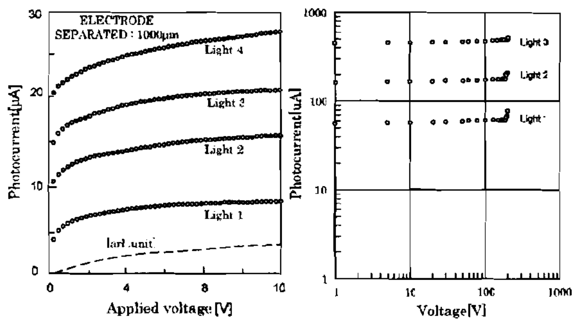


Fig.2. *Block diagram of current-voltage I-V characteristic measurement system PC- controlled.*

3. Results and discussion

In *Fig.3*, the typical photocurrent I_P versus applied voltage V plots by solid lines for a sample having 1000μm-separated electrodes are shown at various levels of optical illumination. Here, the photocurrents were extracted by subtracting the dark current from the device current as-measured at each corresponding bias.

For reference, *Fig.3* (a) illustrates the I_p-V characteristics at different illumination levels of a conventional silicon pin photodiode commercially available. Comparing the plots in *Fig.3* (a) and (b), one finds that the photocurrents under illumination in *Fig.3* (a) increase with the bias applied, while the currents of the commercial photodiode are independent of bias. In case of the commercial one, the active area is limited by the junction area, onto which the light is irradiated through the thin n-type or p-type layer. If the sample is well fabricated, the level of its current would essentially stay at a saturation current level dark determined only by the optical intensity level or in the dark [5]. For our MSM-PD structures, however, the dark current increases with bias, showing that an additional current component is participating, which might be partly due to the incompleteness of the fabrication process of the devices. To exclude the contribution of the dark current, we plotted, in *Fig.3*(a), the photocurrent versus applied bias relationship is plotted. However, *Fig.3*(a) still shows that the photocurrents so obtained increases with bias in spite that the intensity level of illumination was kept at each constant level. This character is different from that of *Fig.3* (b). In addition, the $I_p - V$ plots of the samples having the narrower electrode separations, 20, 100 and 500μm obtained in the same manner were examined.



(a) (b)

Fig. 3 *(a) Typical Ip-V characteristics for a 1000μm-separated electrode sample under various illumination levels. Broken line shows the plot for* $\sqrt{(V+V_{bi})}$ *(arb) when built-in voltage* (V_{bi}) = *0.23V. (b) Photocurrent-voltage* (I_p *-*V *) characteristics of a* pin *photodetector.*

But no appreciable difference in the $I_p - V$ plots showing the current increase with bias was observed. Our explanation for these results is as follows.

Considering the separation between both electrodes from 20μm to 2000μm examined, the region lying between the electrodes is considered to be partially depleted as mentioned previous. Here, let us suppose that the lateral spreading $W(V)$ of the SCR as a function of applied voltage V along the surface optically illuminated follows as[6],

$$W(V) = \sqrt{\beta(V + V_0)} \qquad (1)$$

with, $\beta = 2\varepsilon_s/qN_D$. A single Schottky-barrier prepared in the same process furnishing a back contact has shown the built-in potential of about 0.23eV. Therefore, the bias dependence of the SCR width expressed as Eq.(1) is expected to be as shown by the broken line in Fig.3(a). It was found that, as far as the bias dependence of the plots of the experimental photocurrents concerns, quite similar dependence has been obtained except lower bias regions. In the experimental plots, however, a value bias-independent seems to add to Eq.(1) for each plot. Considering the optical illumination incident onto the whole region between both electrodes, this value is to be the contribution from the diffusion of. Correspondingly, the following experimental (semi-empirical) expression denoting the photocurrent I_P is proposed,

$$\begin{aligned} I_p &= \eta[\alpha W(V) + L] \\ &= \eta[\alpha\sqrt{\beta(V + V_0)} + L] \qquad (2) \end{aligned}$$

where η and α are the fitting parameters which can be determined experimentally. The factor η includes the contributions of the size of the active area, the intensity of incident light, and also quantum efficiency. Another parameter α is the effectiveness ratio of the photocurrent generated in the SCR to the current due to the carriers generated in the undepleted region. L is the diffusion length of carriers photoexcited in the undepleted region. As far as we employ Eq.(2), for a certain sample, the ratio of the value $\alpha\sqrt{\beta}$ to L would be essentially constant. For the case of the sample appeared in *Fig.3*(a), this ratio 1.4 for the "Light1" plot and 1.3 for the "Light4" plot, respectively. It can be said that this substantiates Eq.(2) proposed above.

Another support to the present explanation is the photocurrent behavior observed in the samples made using different resistivity wafers of (9-12)Ωcm, 23Ωcm (40-50)Ωcm which have 2000μm electrode separation. Fig.4 shows *Ip-V* characteristics under a certain illumination intensity in log-log scale after the contribution of the bias-independent term is excluded. One finds that at higher voltages each plot has the same slope of 0.5, suggesting that the current follows the spreading of the SCR given by Eq.(1). The solid line in the figure denotes the line with the slope of 0.5 to guide the eye.

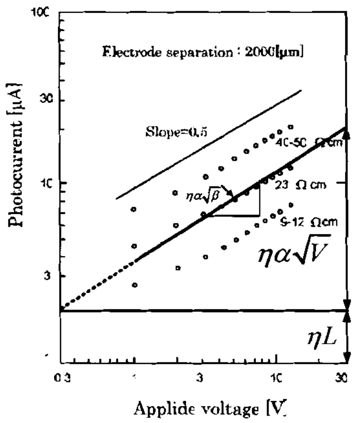


Fig.4. *I_P-V characteristics in log-log scale for the samples made on wafers of three different resistivities, (9-12), 23 and (40-50)Ωcm, which have the same electrode separation of 2000μm.*

The deviation from the straight line of these plots at lower biases can be attributed to the influence of the built-in voltage. Moreover, the levels of the three plots can be understood by considering the difference in the resistivity and thus the donor concentration of the used wafers.

According to the above consideration, the SCR must be much more efficient in generating photocurrents than the residual undepleted neutral region. To confirm this directly, the photocurrent measurements were performed by moving the irradiating position of the focused beam a He-Ne laser. *Fig.5* illustrates the photocurrent distribution profile versus the irradiating position for a 2000μm electrode separated sample, which was obtained by moving the beam at every 15 μm-step. From this figure, it is apparent that the side of the Schottky barrier reverse-biased can generate appreciable photocurrent. Therefore, it can be mentioned that the SCR is quite efficient in generating photocurrents comparing to the residual undepleted region.

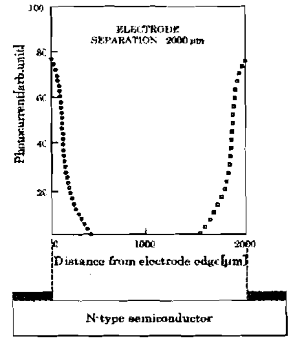


Fig. 5. *Open circles are for photocurrent profile at the edge of the electrode reverse-biased on the left-hand side. When the sign of bias is reversed, the profile given by open squares is observed. Electrode separation is 2000 μm.*

To know the potential profile between the electrodes and thus lateral spreading of the SCR, the numerical simulation based on the simplified one-dimensional (1D) model was carried out. As mentioned earlier, the samples having the electrode separation ranging from 20μm to 2000μm, where the carrier generation takes place mainly within the absorption depth for 633nm wavelength. Therefore, quasi-1D model was assumed for the present simulation [8]. Starting from the following two fundamental equations [9], the calculations were carried out in the domain size of 1000μm for computation. The finite difference method followed by the SOR (successive overelaxation)-Newton method was utilized.

One of the two equations is the carrier continuity equation

$$div(J_n + J_p) + q\frac{d}{dt}(p-n) = 0 \quad (t: time) \qquad (3)$$

where J_n and J_p are the current densities for electrons and holes, n and p are the electron-and hole-concentrations time-dependent, respectively. The ionized space charge is assumed to be time-independent. Furthermore, by introduction of the source and sink to the electron-current and hole-current, these current components satisfy the following relations,

$$divJ_n - q\frac{dn}{dt} = qR \qquad (4)$$

$$divJ_p + q\frac{dp}{dt} = -qR \qquad (5)$$

where R is the generation and/or recombination rate. Here, since we are treating the process under a steady-state condition, the generation rate and recombination rate were set to be equal. The other equation of the two is the Poisson's equation expressed as,

$$div \cdot grad\psi = \frac{q}{\varepsilon_s}(n - p - N_D + N_A) \qquad (6)$$

where ψ is the potential to be determined across the device, and N_D and N_A are the donor concentration and the acceptor concentration, respectively.

In the numerical calculation, the separation of the electrodes was taken as 1000μm and carrier generation /recombination rate R under dark was assumed to be $2.9\times10^{17}cm^{-3}sec^{-1}$. The potential profiles corresponding to several biasing voltages are illustrated in *Fig.6.* As expected, it is apparent that the width of the SCR along the front surface increases with the bias. Eq.(1) predicts the width of the SCR is about 10μm at bias of 10V for the present parameters. Although the boundary between the SCR and the undepleted region of the profile in the figure is not clear but the SCR spreading seems to be coincident with the value expected from Eq.(1). The calculations for larger value of R for illuminated condition were performed, assuming the value of R ten times larger than that of the dark condition. The results revealed that the current level was elevated but the corresponding potential profile itself remained substantially unchanged.

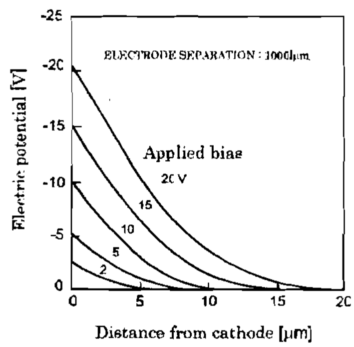


Fig.6. *Bias-dependence of potential profiles near the reverse-biased Schottky junction obtained from numerical simulation based on quasi-1D model of 1000μm-separated electrodes.* Generation rate = $2.9\times10^{17}cm^{-3}sec^{-1}$ *was assumed.*

The series resistance of this sample of 1kΩ has been examined from the measurements of the signal response [5]. At $I_P = 30\mu A$, for instance, the voltage drop would be 0.038V, which is quite small comparing to the applied biases examined. The physical parameters used for calculations are given in Table 1.

Table 1 List of symbols and their value used in numerical calculation and in the text

Symbol	Value
V	1-20V
V_{bi}	0.23 eV
$W(V)$	$\sqrt{[\beta(V_{bi}+V)]}$
$\beta = 2\varepsilon_s / qN_D$	$16.5\,\mu m^2/V$
ε_s	$1.054\times10^{-10}F/m$
q	$1.60\times10^{-19}C$
N_D	$8\times10^{13}cm^{-3}$
L	70 μm
k	2.6

4. CONCLUSION

The laterally spreading of the space-charge-region (SCR) along the surface of planar molybdenum n-type silicon molybdenum structures has been examined experimentally and numerically.

Bias-controllable photocurrent characteristics using planar Mo/n-Si/Mo systems with depleted and undepleted region at the active area were examined and confirmed experimentally. It can be concluded that one can control the photocurrent in a planar MSM structure under dc optical illumination by varying bias. As it were, one can give these structures an electronic iris effect by introducing an undepleted neutral region between electrodes, maintaining the function of changing the optical signal into electronic signal. The neutral region as well as the depleted region plays a key role for this effect. Furthermore, it was revealed that the potential profile and the spreading at the font surface of the SCR of such MSM photodetector structures are approximately but substantially described by the equation semi-empirically proposed based on the simple 1D model.

5. ACKNOWLEDGEMENT

The authors are thankful to Assoc.Dr.W. Titiroongruang of King Mongkut's Institute of Technology Ladkrabang for many helpful discussions. Continuous encouragement of Dr.R.P.Phukkamarn of Sripatum University is deeply appreciated. This work was supported in part by The Thailand Research Fund.

6. REFERENCES

[1] Berger PR. *MSM photodiodes.* IEEE Potentials, Apr/May, Vol.25, 1996.

[2] Seto M, Leduc J-V, Lammers MF. "*Al-n-Si Double-Schottky Photodiodes for Optical Storage Systems,*" 27th European Solid-State Device Res.Conf.Sept.1997.

[3] Averine SV, Chan YC, Lam YL."*Geometry optimization of interdigitated Schottky-barrier metal-semiconductor-metal photodiode structures,*"Solid-State Electron, Vol.45.pp.441,2001.

[4] Masui T, Khunkhao S, Kobayashi K, Niemcharoen S, Supadech S, Sato K, "*Photosensing properties of interdigitated metal semiconductor-metal structures with undepleted region,*" Solid-State Electron. Vol.43, pp.1811,2003

[5] Takano H, Kimura H,Ando T, Niemcharoen S, Yasumura Y,Sato K, "*Optical response of planar Mo/n-Si/Mo structures with long neutral region and Schottky barriers at both ends,*" Solid-State Electron,Vol.44,pp.216. 2000

[6] Sze SM, *Physics of semiconductor devices*, 2nd ed. New York:John Wiley;1981.

[7] Grove As, *Physics and technology of semiconductor devices.* New York: John Wiley, 1967.

[8] Snowden CM. *Semiconductor device modeling, London,* Peter Peregrinus,1988.

[9] Selberherr S, *Analysis and simulation of semiconductor devices,* Wien Springer-Verlag,1984.