The Impact of Climate Change on Coastal Ecosystems

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Abstract*²D,Q$V6E FHOOV SUREDEO\ VKRZ EHWWHU SHUIRUPDQFH WKDQ*D6EFHOOVLQORZWHPSHUDWXUHWKHUPRSKRW RYROWDLFV\VWHPVGXH WR ORZHU EDQGJDS KRZHYHU IHZ H[SHULPHQWV SURYHG WKLV SKHQRPHQRQ VR IDU ,Q WKLV SDSHU QXPHULFDO VLPXODWLRQ LV XVHG WR HYDOXDWH *D,Q$V6E DQG *D6E FHOO ZLWK VLPLODU VWUXFWXUHV XQGHU GLIIHUHQWUDGLDWLRQWHPSHUDWXUHV:HRXQGWKDW*D,Q$V6EFHOOVZLWK QW\SHHPLWWHUVVKRZVOLJKWO\KLJKHURXWSXWSRZHUGHQVLWLHVFRPSDUHG ZLWK WKDW RI *D6E FHOOV ZLWK QW\SH HPLWWHUV EHORZ .EODFNERG\UDGLDWLRQDQGWKHSRZHUGHQVLW\RIWKHODWHUFHOOVZLOO VXSSUHVV WKH IRUPHUV DERYH WKLV WHPSHUDWXUH SRLQW 'XULQJ WKH WHPSHUDWXUHUDQJHRIa.WKHHIILFLHQFLHVRI*D6EFHOOV DUHDERXWZLFHRI*D,Q$V6EFHOOVLISHUIHFWILOWHUVDUHXVHGWRSUHYHQW WKHHPLVVLRQRIWKHQRQJZDYHOHQJWKSKRWRQV6HYHUDO SDUDPHWHUV WKDW DIIHFW WKH *D,Q$V6E FHOO ZHUH DQDO\]HG VXFK DV GRSLQJSURILOHVWKLFNQHVVHVRI*D,Q$V6EHSLWD[LDOOD\HUDQGVXUIDFH UHFRPELQDWLRQYHORFLW\7KHQRQSMXQFWLRQVLHQW\SHPLWWHUVDUH EHWWHUIRU*D,Q$V6EFHOOIDEULFDWLRQZKLFKLVVLPLODUWRWKDWRI*D6E FHOOV

Keywords—
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WKHRUHWLFDOFRQGLWLRQEHFDXVHWKH*D,Q$V6E FHOOKDVWKHORZHU EDQGJDSWKDQWKDWRIWKH*D6EFHOO'U4LXH[SODL QHGWKDW WKHUH PD\ EH VRPH OHDNDJH FXUUHQW SUREOHPV ZLWK WKH *D,Q$V6EFHOOZKLFKDFXVHGWKHDEQRUPDOSKHQR PHQRQWKH SRZHUGHQVLW\RI*D,Q$V6EFHOOZRXOGEHHQKDQFH GLIWKHFHOO VWUXFWXUHDQGPDQXIDFWXULQJSURFHVVZHUHRS WLPL]HG 6LQFHQRPRUHFRPSDULVRQGDWDFDQEHREWDLQH GLWLV YDOXDEOHWRPDNHDWKHRUHWLFDOFDOFXODWLR QIRUHYDOXDWLRQRIWKH SHUIRUPDQFHRI*D6EDQG*D,Q$V6EFHOOV,QWKLVSD SHUWKH SHUIRUPDQFHRIFHOOVZLWKIRXUGLIIHUHQWVWUX FWXUHV*D6EFHOOV ZLWKSDQGQW\SHPLWWHUV*D,Q$V6EFHOOZLWKSD QGQW\SH HPLWWHUVDUHHYDOXDWHGXQGHUGLIIHUHQWUD GLDWLRQVHFWUXPV *D6EFHOOVZLWK=QGLIIXVHGSHPLWWHUVDUHWKH PRVWGHYHORSHG FRQFOXVLRQV

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UHIOHFWRU%65LVQRWXVHGWKHYDOXHRIS LVVHWD W[a FPVIRUGLVFXVVLRQDQGZLOOEHVHWDWDKLJKYDO XHRIFPV IRUILQLDOFRPSDULVRQVEHFDXVHQRZLQGRZOD\HU LVXVHGWKH DERYHWZRVHWWLQJVDUHXVHGWRNHHSXQLW\ZLW KWKHFRPPHUFLDO =QGLIXVHG*D6EFHOOV7KHLQWHUIDFHUHFRPELQD WLRQYHORFLW\ EHWZHHQ*D6EVXEVWUDWHDQG*D,Q$V6EHSLWD[LD OOD\HULVVHWDW FPV)LJVKRZV*D,Q$V6EFHOOVWUXFWXUHZLWK7HGLI XVHG SHPLWWHUVDQGWKHLQWHUQDO7HSURILOHV7KHU HDUHQRGLIXVLRQ GDWDWRLQYHVWLJDWHWKH7HGLIXVLRQLQ*D,Q$ V6EWKXVWKH7H GRSLQJSURILOHVZKLFKREH\WKHFRPSOHPHQWDU\H UURUIXQFWLRQ

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$QWLUHIOHFWLRQOD\HU6L1OD\HU PP
*ULGDUHD6XUIDFHDUHD

7KLFNQHVVRI1*D6EVXEVWUDWH PP
&DUULHUFRQFHQWUDWLRQRI1*D6E VXEVWUDWH FPu

7KLFNQHVVRI1*D,Q$V6E HSLWD[LDOOD\HU a PP
1*D,Q$V6EGRSLQJ7H GRSLQJ FPu

=QSURILOHVKRZ QLQ)LJ 3W\SHHPLWWHU=QGRSLQJ E

(OHFWURQPRELOLW\LQ *D,Q$V6E PP P_PLQ FP 9 V

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N N N_D A UHI P FP 9 V

+ROHPRELOLW\LQ*D,Q$V6E PD[PLQ PLQ

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ZHUHDSSUR[LPDWHO\XVHGIRUVLPXODWLRQDVVKR ZQLQ)LJE

7KH FDUULHU FRQFHQWUDWLRQ RI S*D6E VXEVWUDWH DQG S*D,Q$V6E HSLWD[LDO OD\HU LV îFP WKH RWKHU SDUDPHWHUVRIQRQSFHOOVDUHVLPLODUWRWKDW SRQQFHOOVDV VKRZQLQ7DEOHV,DQG,,

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RUGHUWRFKRRVHWKHRSWLPDOSDUDPHWHUVIRUW KH*D,Q$V6EFHOO

A. Effect of the Diffusion Depth on Cell Performance

7KHJUDGLHQW=QRU7HGRSLQJFRXOGEHIRUPHGE\Y DSRU GLIIXVLRQDQGWKHLQWHUQDOTXDQWXPHIILFLHQF \,4(RIWKH *D,Q$V6EFHOOFRXOGNHHSDFRQVLGHUDEOHYDOXH ZLWKRXWD ZLQGRZOD\HUWRUHGXFHWKH$S$YDOXH,QWKLVFRQG LWLRQWKHS YDOXHLVVHWDW FPVDQGWKHWKLFNQHVVRIWKH1RU 3*D,Q$V6EHSLWD[LDOOD\HULV3PLQWKLVVLPXODWL RQSURFHVV)LJVKRZVWKH,4(RIWKH*D,Q$V6EFHOOVZLWKSDQGQ W\SH HPLWWHUVXVLQJGLIIHUHQWGLIIXVLRQGHSWK%R WKWKH,4(GDWD GHFUHDVHZLWKWKHLQFUHDVLQJRIGLIIXVLRQGHS WKWKXVOLJKW GRSLQJLVEHWWHUIRUFHOOGHVLJQDQGWKHGHSWK RI3PZLOOEH FKRVHQ IRU ERWK FHOOV LQ WKH IROORZLQJ VLPXODWLRQV 7KH *D,Q$V6EFHOOVZLWKQHPLWWHUVVKRZEHWWHU,4(WKDQRIWKH FHOOVZLWKSHPLWWHUVLQWKHORQJZDYHOHQJWK VUHJLRQ

B. Effect of the Thickness of GaInAsSb Epitaxial Layer on Cell Performance

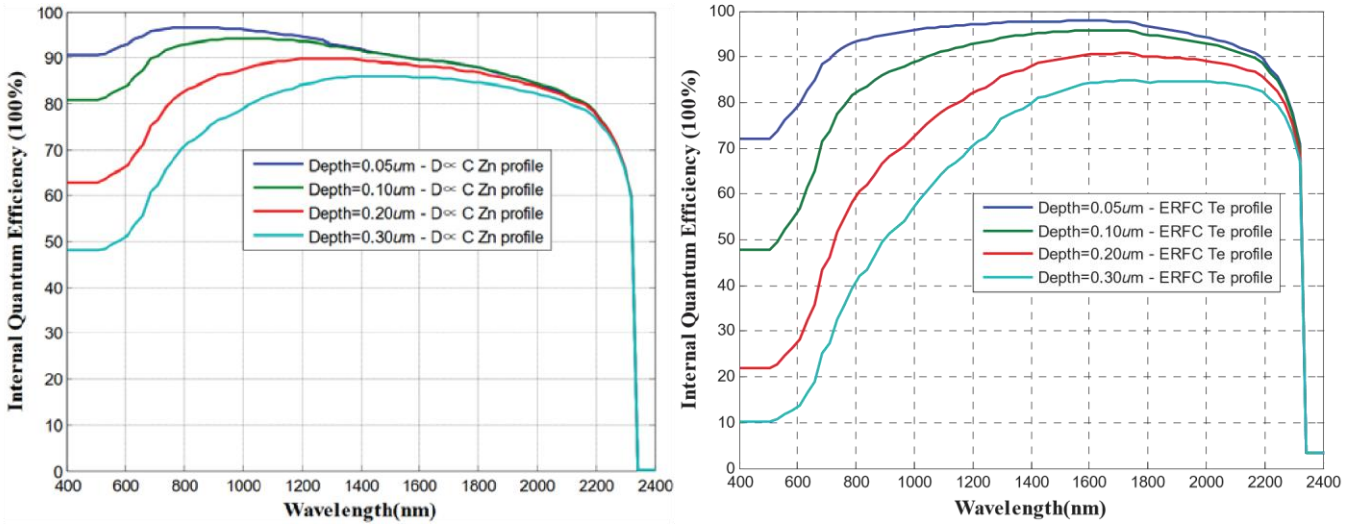
7KHEDVHUHJLRQRI*D,Q$V6EFHOOVFRQWULEXWH VWKHODUJHVW SDUWRI,4(LQWKHORQJZDYHOHQJWK3KRWRJHQHUD WHGPLQRULW\

FDUULHUVZRXOGQRWEHIXOO\FROOHFWHGLIWKHE DVHUHJLRQZDVWRR WKLQ&RQYHUVHO\PLQRULW\FDUULHUSDLUVZRXO GUHFRPELQHLIWKH EDVHUHJLRQZDVWRRWKLFN)LJVKRZVWKH,4(RIWKH *D,Q$V6EFHOOVZLWKSDQGQW\SHHPLWWHUVXVLQJ GLIIHUHQW

WKLFNQHVVRIWKH*D,Q$V6EHSLWD[LDOOD\HUWKH GLIIXVLRQGHSWK LV3PDQGWKH*SYDOXHLVVHWDWFPV$VIRUWKHFHOO V

ZLWKSHPLWWHUVWKH,4(ZLOOGHFUHDVHEHIRUHQP DQG LQFUHDVHDIWHUWKLVZDYHOHQJWKDORQJZLWKW KHGHHSHQLQJRIWKH

1*D,Q$V6EHSLWD[LDOOD\HU$VIRUWKHFHOOVZLWK QHPLWWHUV WKH,4(ZLOONHHSFRQVWDQWEHIRUHQPDQGLQFUH DVHDIWHU WKLVZDYHOHQJWKDORQJZLWKWKHGHHSHQLQJRI WKH3*D,Q$V6E HSLWD[LDOOD\HU7KHDERYHGLIIHUHQWYDULDWLR QWHQGHF\PD\EH FDXVHGE\WKHGLIIHUHQWGLIIXVLRQGHSWKEHWZH HQKROHVDQG HOHFWURQVLQ*D,Q$V6EOD\HUV

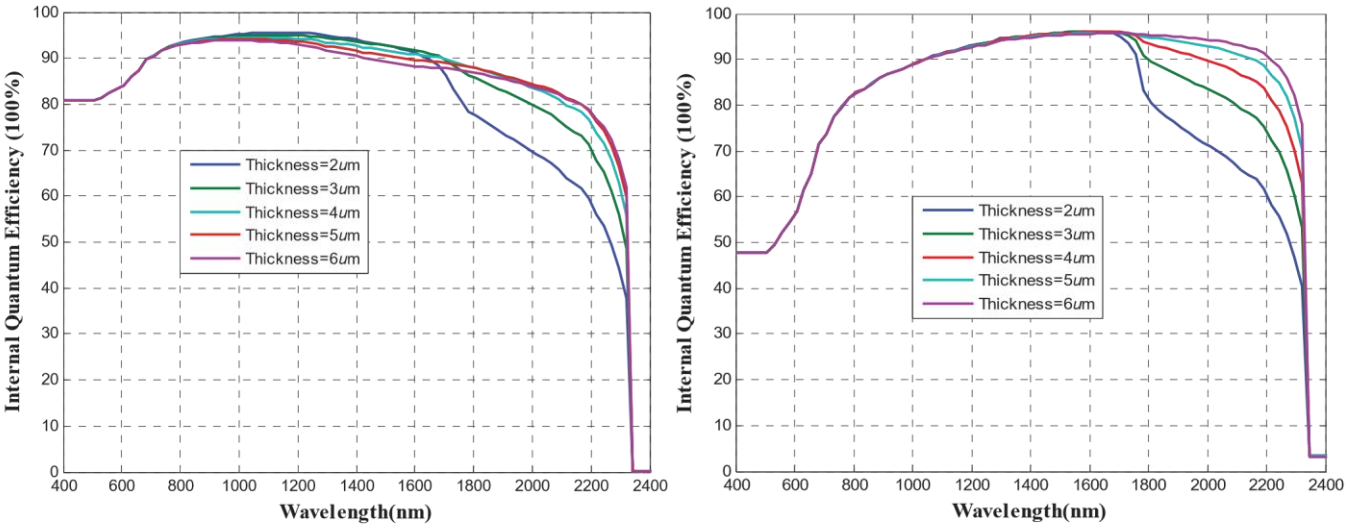


(a) (b)

Fig. 3 (a) IQE of the GaInAsSb cells with p-type emitters, and (b) n-type emitters using different diffusion depth

C. Effect of the Surface Recombination Velocity on Cell Performance

The average IQE of GaInAsSb cells with uniform doped emitters will decrease rapidly if the *S* value surpasses 10^5 cm/s [14], thus a window layer would be needed to reduce the *S* value; while the high *S* value will not affect the IQE heavily if gradient doped emitters are used. Fig. 5 shows the calculated IQE of the GaInAsSb cells with p and n-type emitters using different *S* values. The thickness of N or P-GaInAsSb epitaxial layer is 5 μm and the diffusion depth is 0.1 μm in this simulation process. The IQE of both cells only decrease in the short wavelength, thus the cell performance will not decrease rapidly.



(a) (b)

)LJD,4(RIWKH*D,Q$V6EFHOOVZLWKSW\SHHPLWWHUVDQGEQW\SHHPLWWHUVXVLQJGLIIHUHQWWKLFNQHVVR I*D,Q$V6EHSLWD[LDOOD\HU

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7KHVKRUWFLUFXLWFXUUHQW,VFRI*D,Q$V6EFHO OVZLOOEH ODUJHUWKDQWKDWRI*D6EFHOOVKRZHYHUWKHR SHQFLUFXLW YROWDJH9RFDQGILOOIDFWRU))RIWKHIRUPHUFHOO ZLOO GHFUHDVHGXHWRWKHORZEDQGJDS7KHFHOOSDUD PHWHURI,VF9RF

DQG))VKRXOGEHFRQVLGHUHGRYHUDOOWKHRXWSX WSRZHUGHQVLW\ DQGFHOOHIILFLHQF\DUHWKHXOWLPDWHLQGLFDWR UVIRUSHUIRUPDQFH FKHFN,QWKLVVHFWLRQWKHRSWLPDOFHOOVWUXF WXUHZLOOEHFKRVHQ IRU WKHLU HYDOXDWLRQ SHUIRUPDQFHV XQGHU a .EODFNERG\ UDGLDWLRQ XVHIXO FRPSDULVRQ UHVXOWV ZLOO EH REWDLQHG

IRUFRPSDULVRQ7KHGLIIXVLRQGHSWKLV3PDQGWK H*YDOXH LVFPVIRUERWKWKHSRQQRULQYHUWHGVWUXFWX UHV7KHJLUG DUHDSHUFHQWLVVHWDWIRUNHHSXQLW\ZLWKWK DWRIWKH *D6EFHOO7KHQWLUHIOHFWLRQ$5&OD\HURIWKH=QGLIIXVHG *D,Q$V6EIDEULFDWHGE\)URXQKRIHULV3WKLFNDQRGLF

R[LGHUHIUDFWLYHLQGH[Q§7KH3P$5&OD\HUPD\EH WRWKLQIRUWKH*D,Q$V6EFHOOVDQGWKHPLQLPX P5()YDOXH

$5&OD\HUIRUWKH*D,Q$V6EFHOOV7KHWKLFNQHVVR IWKH 1*D,Q$V6EHSLWD[LDOOD\HUIRUWKHSRQQVWUXFW XUHLVVHWDW

3PWKH,4(EHIRUHQPZLOOGHFUHDVHZLWKWKHGHHSH

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)LJD,4(RIWKH*D,Q$V6EFHOOVZLWKSW\SHHPLWWHUVDQGEQW\SHHPLWWHUVXVLQJGLIIHUHQW*YDOXHV

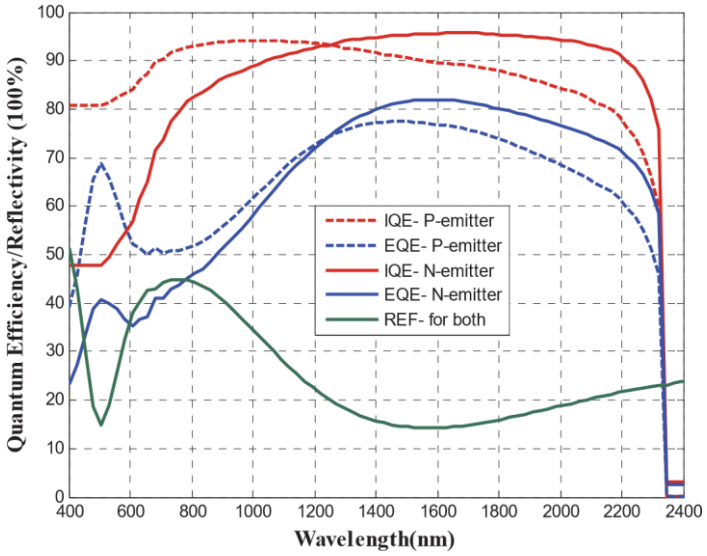
A. Selection of the GaInAsSb and GaSb Cell Structure for Performance Evaluation

)LJVKRZV,4(H[WHUQDOTXDQWXPHIILFLHQF\(4(DQG UHIOHFWLYLW\5()RIWKH*D,Q$V6EZLWKSDQGQHPLW WHUVXVHG QLQJ RIWKH1*D,Q$V6EOD\HU7KHWKLFNQHVVRIWKH3*D,Q$V6E HSLWD[LDOOD\HURUSRQQVWUXFWXUHLVVHWDW3PWKH,4(ZLOO LQFUHDVH ZLWK WKH GHHSHQLQJ RI 3*D,Q$V6E OD\HU WKH

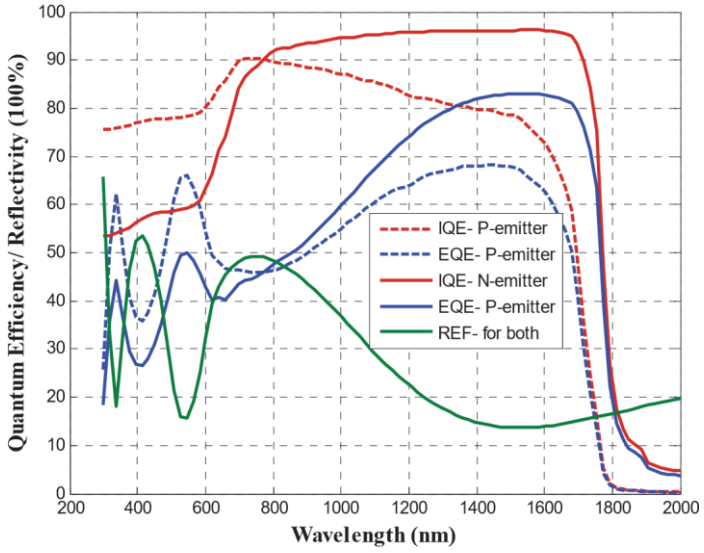
WKLFNQHVVRI3P
LVFKRVHQIRUFRQVLGHULQJWKHFRVWRIWKH

HSLWD[LDOSURFHVV
7KH,4(RI*D,Q$V6EFHOOVZLWKQW\SHPLWWHUVLV
KLJKHU
WKDQWKDWRIFHOOVZLWKSW\SHPLWWHUVLQWKH
ORQJZDYHOHQJWK

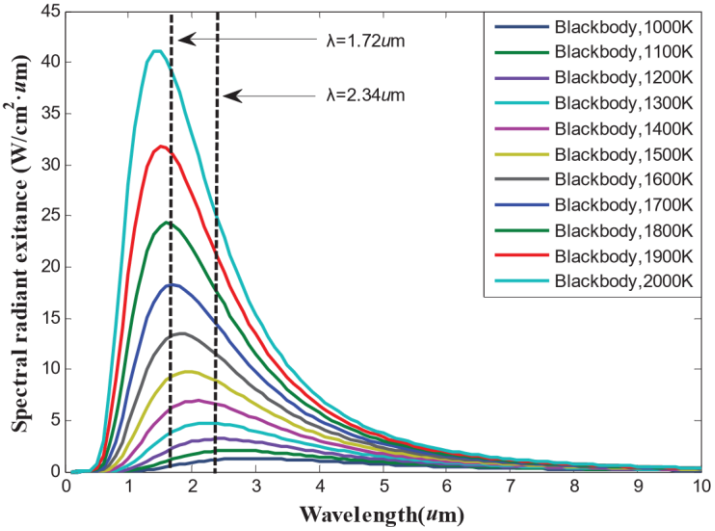
UHJLRQWKLVSKHQRPHQRQLVFDXVHGE\WKHGLVDUL
WLHVEHWZHHQ
WKHGLIIXVLRQOHQJWKRIHOHFWURQVDQGKROHVLQ
*D,Q$V6E7KH
*D,Q$V6EFHOOVZLWKQW\SHPLWWHUVZLOOVKRZEH
WWHURXWSXW
SRZHUGHQVLW\LQ739V\VWHPVWKDQWKDWRISW\SH
PLWWHUV
ZKLFKDUHVLPLODUWR*D6EFHOOV



)LJ,4((4(DQG5()RIWKH*D,Q$V6EFHOOVZLWKSDQGQW\SHPLWWHUVXVHGIRUFRPSDULVRQ



)LJ,4((4(DQG5()RIWKH*D6EFHOOVZLWKSDQGQW\SHPLWWHUVXVHGIRUFRPSDULVRQ



)LJ6SHFWUXPGLVWULEXWLRQVRIa.EODFNERG\UDGLDWLRQ PLWWHUV EHORZ.EODFNERG\UDGLDWLRQDQGWKH3PD[RIWKHO DWHU FHOOZLOOVXSSUHVVWKHIRUPHUDERYHWKLVWHPS HUDWXUHSRLQW7KH *D,Q$V6E FHOOV ZLWK SW\SH HPLWWHUV VKRZ KLJKHU 3PD[FRPSDUHGZLWKWDWRI*D6EFHOOVZLWKSW\SHHPL WWHUVEHORZ

B. The Cell Performance under 1,000~2,000 K-Blackbody Radiation with No Filters

)LJVKRZVWKHVSHFWUXPGLVWULEXWLRQVRIa .EODFNERG\ UDGLDWLRQ 7ZR GDVKHG OLQHV LQ)LJ GHPRQVWUDWHWKHFXWRIIZDYHOHQJWKVIRU*D6E DQG*D,Q$V6E FHOOVWKHOHIW3P IRUH9*D6EFHOOVDQGWKHULJKW

3PIRUH9*D,Q$V6EFHOOV7KHSRZHUGHQVLWLHV ZLWKLQWKHFXWRIIZDYHOHQJWKRI*D,Q$V6EFHOOV DUHPXFK ODUJHUWKDQWKDWRIWKH*D6EFHOOVGXULQJWKH WHPSHUDWXUHUDQJH RIa.

7KH,VF9RFDQG))RIIRXW\SHVRI739FHOOVXQGHU a.EODFNERG\UDGLDWLRQDUHVKRZQLQ)LJ7KH ,VFRI*D,Q$V6EFHOOVDUHPXFKODUJHUWKDQ*D6EFHO OVGXULQJ WKHFRPSOHWHWHPSHUDWXUHUDQJHZKLOHWKH9RF DQG))RIWKH IRUPHU FHOOV DUH ORZHU WKDQ WKDW RI WKH ODWHU FHOOV %\ PXOWLSO\LQJWKHDERYHWKUHHSDUDPHWHUVWKH PD[LPXPRXWSXW SRZHUGHQVLW\3PD[FRXOGEHREWDLQHGDVVKRZQLQ) LJ 7KH3PD[RI*D,Q$V6EFHOOVZLWKQW\SHHPLWWHUVDU HODUJHU WKDQWKDWRISW\SHHPLWWHUVGXULQJWKHWHPSH UDWXUHUDQJHRI a.7KH3PD[RI*D6EFHOOVZLWKQW\SHHPLWWHUV DUHODUJHUWKDQWKDWRISW\SHHPLWWHUVGXULQJ WKHWHPSHUDWXUH UDQJHRIa.WKHFRPSDULVRQUHVXOWVZLOOUHYHUV H DIWHU.GXHWRWKHVXSHULRU))RI*D6EFHOOVZLWK SHPLWWHUV

*D,Q$V6EFHOOVZLWKQW\SHHPLWWHUVVKRZVOLJ KWO\KLJKHU 3PD[FRPSDUHGZLWKWDWRI*D6EFHOOVZLWKQW\SHH

C. The Cell Performance under 1,000~2,000 K-Blackbody Radiation with Perfect Filters

2SWLFDOILOWHUVZHUHFRPPRQO\XVHGLQ739V\VW HPVWR SUHYHQWWKHHPLVVLRQRIQRQDEVRUEHGSKRWRQV DQGWKHFHOO HIILFLHQFLHVZLOOHHQKDQFHJUHDWO\LIHIILFLHQWI LOWHUVZHUHXVHG)LJVKRZVWKHRXWSXWSRZHUGHQVLW\DQGFHOOHII LFLHQF\ XQGHUa.EODFNERG\UDGLDWLRQZLWKSHUIHFWILOW HUV 7KHSHUIHFWILOWHUVKDYHWKHIXQFWLRQWKDWW KHQRQDEVRUEHG SKRWRQVOt PIRU*D6EDQGP Ot PIRU*D,Q$V6EP ZHUHDOOSUHYHQWHGWRWUDQVPLWWRWKHFHOOV XUIDFH7KHRXWSXW SRZHUGHQVLWLHVRIWKHIRXFHOOVDUHVDPHWRW KDWLQ)LJ ZKLOHWKHFHOOHIILFLHQFLHVFKDQJHVXEVWDQWL DOO\7KH*D6EFHOO ZLWKQW\SHHPLWWHUVVKRZVWKHHIVWHIILFLHQF\ DPRQJWKHIRXU FHOOVDQGLWVHIILFLHQF\LVDERXWWZLFHWKDWFR PSDUHGZLWK *D,Q$V6EFHOOVGXULQJWKHWHPSHUDWXUHUDQJHR Ia .

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7KH*D,Q$V6EFHOOVZLWKGLIIXVHGHPLWWHUVZH UHDQDO\]HGLQ WKLV SDSHU DQG WKH QRQS VWUXFWXUHV VKRZ WKH EHWWHU SHUIRUPDQFH WKDQ WKDW RI SRQ VWUXFWXUHV 7KH $9 RI *D,Q$V6EFHOOVUHDFKHGDERXWP9ZLWKRXWWKHZ LQGRZ OD\HUGXHWRWKHEXLOWLQHOHFWULFDOILHOGFD XVHGE\JUDGLHQW GRSLQJ7KHSHUIRUPDQFHRI*D,Q$V6EDQG*D6EFHOOV ZHUH HYDOXDWHGXQGHUa.EODFNERG\UDGLDWLRQZLWK QR DQGSHUIHFWILOWHUV:HRXQGWKDW*D,Q$V6EFHOO VZLWKQW\SH HPLWWHUVVKRZVOLJKWO\KLJKHU3$[FRPSDUHGZL WKWKDWRI*D6E FHOOVZLWKQW\SHHPLWWHUVEHORZ.EODFNERG\UD GLDWLRQ

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+ &KRL & :DQJ * 7XUQHU 0 0DQIUD ' 6SHDUV * &KDUDFKH / 'DQHOOVRQ"HSR\+LJKSHIRUPDQFH*D,Q$V6EWKHUPRSKRWRY ROWDLF GHYLFHVZLWKDQ$O*D$V6EZLQGRZ$SSOLHGSK\VLFVOHWWHU V
5 0DJUL $ =XQJHU + .URHPHU (YROXWLRQ RI WKH EDQGJDS DQG EDQGHGJH HQHUJLHV RI WKH ODWWLFHPDWFKHG *D,Q$V6E» *D6E DQG *D,Q$V6E»,Q$VDOOR\VDVDIXQFWLRQRIFRPSRVLWLRQ-RXUQDORIDSSOLHG SK\VLFV 0:'DVKLHOO-)%HDXVDQJ+(KVDQL*1LFKROV'0'HSR\5 'DQHOOVRQ 3 7DODPR .' 5DKQHU (- %URZQ 65 %XUJHU 4XDWHUQDU\ ,Q*D$V6E WKHUPRSKRWRYROWDLF GLRGHV (OHFWURQ 'HYLFHV ,(((7UDQVDFWLRQVRQ /0)UDDV -($YHU\ +; +XDQJ 7KHUPRSKRWRYROWDLF IXUQDFHJHQHUDWRU IRU WKH KRPH XVLQJ ORZ EDQGJDS *D6E FHOOV 6HPLFRQG6FL7HFK66
$: %HWW 29 6XOLPD *D6E SKRWRYROWDLF FHOOV IRU DSSOLFDWLRQV LQ 739JHQHUDWRUV6HPLFRQG6FL7HFK66
.4LX$+D\GHQ'LHFWWKHUPDOWRHOHFWULFDOHQHUJ\FRQYH UVLRQXVLQJ YHU\ ORZ EDQGJDS 739 FHOOV LQ D JDVILUHG IXUQDFH V\VWHP (QHUJ\ &RQYHUVLRQDQG0DQDJHPHQW :5 &KDQ 3 %HUPHO 5& 3LODZD3RGJXUVNL &+ 0DUWRQ .) -HQVHQ -- 6HQNHYLFK -' -RDQQRSXORV 0 6ROMDþLü , &HODQRYLF 7RZDUGKLJKHQHUJ\GHVW\KLJKHIILFLHQF\DQGPRGHUDWH WHPSHUDWXUH FKLSVFDOH WKHUPRSKRWRYROWDLFV 3URFHHGLQJV RI WKH 1DWLRQDO $FDGHP\ RI6FLHQFHV &RQIHUHQFH5HRUGRIWKH7ZHQW\6L[WK,(((,(((SS