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Study of the Photo thermal Response of a Mono facial Solar Cell in Dynamic Regime under a Multispectral Illumination and under magnetic field

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Abstract: ***In this article, we present the study of the photo thermal response of a monofacial silicon solar cell illuminate by a multispectrallightforaconstantmodulatedfrequencyandundermagneticfield.aftertheresolutionoftheequationofcontinuityoftheminoritycarriersofloads,weestablishwiththehelpofsomejustifiedapproximations,theequationsofheat in the presence of an optical sourceofheatandthenewboundaryconditionsallowingtosolvethose. Thedensityofminoritycarriersinexcess,theamplitudeofthevariationoftemperatureandtheheatfluxdensitywerestudiedandanalyzedfordifferentangularpulsesandfordifferentvaluesofthemagneticfieldand ratesofrecombinationatthejunction.RepresentationsofNyquistand Bodeplotsofthethermaldynamicimpedanceresultedinanequivalent electricalcircuitofthephotocell.***

Keywords: solar cell- frequency modulation- magnetic field - Capacitive effect ,inductive effect, photo thermal.

I. INTRODUCTION

Wewillmakethestudyofaphotovoltaiccellmonofacialtosiliconlitbyaconstantmultispectrallightinfrequentialdynamicmodeandundertheeffectofamagneticfield.Inthispresentarticle,weinitiallywillmakeashortdescriptionofthephotovoltaiccellbifacialandthenwewillseetheevolutionofthecoefficientofdiffusionaccordingtotheintensityofthemagneticfield,thedensityofminoritycarriersaccordingtothedepthandoftheintensityofthemagneticfield.Wethenwillstudythethermalbehaviorofthephotovoltaiccell.Wealsowillstudytheinfluenceofthepulsationontheseparameters.

THEORY

Photovoltaic response (minority carriers' density in excess):

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We consider solar silicon with a Back Surface Field(B.S.F)for the structure n+pp+ (LeQuangNam*etal*.,1992).

Given that the contribution of the base to the Photocurrent is larger than that of the emitter(Barro*etal*.,2001;Lemrabott*etal*.,2008),the univariate analysis will only be developed in the base region. In addition, we consider the hypothesis of Quasi-Neutral Base(Q.N.B)neglecting the crystal field with in the solar cell. InFig.1, wepresentaschematicsketchofa multicrystallinesiliconsolarcellwithaBackField(BSF)typicallyn+-p-p+inamagneticfield.

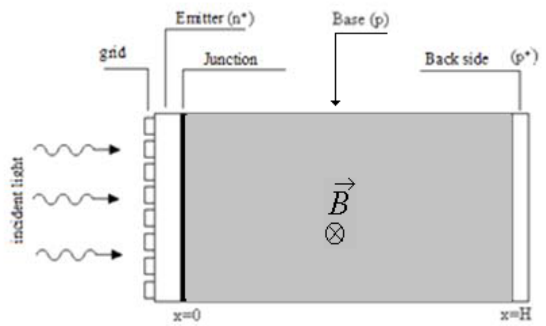

Fig.1:Amonofacialsolarcellunderamultispectralilluminationfromamodulatedfrequencyandundermagneticfield

Whenthephotovoltaiccellreceivesasolarradiation,thetransformationisdoneinthreestages:

- ✓ absorption of the photons by material
- ✓ creationofpairselectron-positronpairwhichwillbeseparatedbyanintenseelectricfieldonthelevelfromthezoneofspacecharge
- ✓ collection oftheparticlesinanexternalcircuit

Thesolarcellissubjectedtoaconstantmultispectralilluminationfromasourceofamodulatedfrequencyandundermagneticfieldeffectandthephenomenaofgeneration,diffusionandrecombinationofphotogeneraedcarriersinthebaseareconsidered.These phenomena are governed by the continuity equation:

$$D(\omega,B)\frac{\partial^2\delta(x,t,\omega,B)}{\partial x^2}-\frac{\delta(x,t,\omega,B)}{\tau}+G(x,t)=\frac{\partial\delta(x,t,\omega,B)}{\partial t}$$

(1)

$\delta(x,t)$

thedensityoftheminoritycarriersinthebasewhichcanbewritteninthe form:

$$\delta(x,t)=\delta(x).e^{i.\omega.t} \quad (2)$$

$g(x,t)$ theopticalrateofgenerationgivenbytheexpression:

$$G(x,t) = g(x)\cdot e^{i.\omega.t} \quad (3)$$

$\delta(x)$ and $g(x)$ representrespectivelythespatialcomponentsofthecarrierdensityandtherateofgeneration.

Andtheterm $e^{i\omega t}$ representsthetimecomponentforthecarrierdensityandtherateofopticalgeneration.

Comparingtheaboveequationsforwhichincidentopticalbeamandthedensityofphotogeneratedcarriers,theEq.(1)issimplifiedandbecomesasfollows:

$$\frac{\partial^2\delta(x)}{\partial x^2} - \frac{\delta(x)}{L(\omega,B)^2} + \frac{g(x)}{D(\omega,B)} = 0 \quad (4)$$

ThecoefficientDwhichdescribesthediffusivecharacteroftheminoritycarriersinmaterial,isfunctionofthefrequencyofmodulationandtheintensityofthemagneticfieldandisgivenbytheexpression:

$$D(\omega,B) := D0\frac{\left[1+\tau^2\cdot\left(\omega c(B)^2+\omega^2\right)+i\cdot\omega\cdot\tau\cdot\left[\tau^2\cdot\left(\omega c(B)^2-\omega^2\right)-1\right]\right]}{4\cdot\tau^2\cdot\omega^2+\left[1+\tau^2\left(\omega c(B)^2-\omega^2\right)\right]^2} \quad (5)$$

And $\dfrac{1}{L(\omega)^2} = \dfrac{1}{Ln^2}\times(i\omega\tau+1)$ (6)

Where $L(\omega,B)$ isthecomplexscatteringlength.The spatial componentg(x)isarateofopticalgenerationofelectronholepairsforamultispectralilluminationfromaconstantmodulatedfrequencyandasitreflectstheentirespectrumofusefulradiationincidentonthesolarcell,itisthusgivenbythefollowingexpression:

$$g_{\gamma}(x) = \sum_{\lambda_0}^{\lambda_g}\alpha(\lambda)\phi(\lambda)(1-R(\lambda))(\xi e^{-\alpha(\lambda)x} + \chi e^{-\alpha(\lambda)(H-x)})$$

(7)

Where $\alpha(\lambda)$ and $R(\lambda)$ representrespectivelytheabsorptioncoefficientandthereflectioncoefficientofthematerialforagivenwavelengthλ;

$\phi(\lambda)$ Isthefluxofincidentphotons.

λ_g:Wavelengthofcutofthesemiconductorestimatedat1,12µm

λ_0 :Theminimalwavelengthofthesource luminousisequalto0,3µm[36];

H:thesolarcellbasethickness.

τ Istheaveragelifetimeoftheminoritycarriersofload.

Thedensityofminoritychargecarriersinexcess (electrons)isgivenbytheexpression:

$$\delta(x) = A(\omega)\cosh\left(\frac{x}{L(\omega)}\right) + B(\omega)\sinh\left(\frac{x}{L(\omega)}\right) + \sum_{\lambda_0}^{\lambda_g}k(\omega,\lambda)(\xi e^{-\alpha(\lambda)x} + \chi e^{-\alpha(\lambda)(H}$$

(8)

With

$$k(\omega,\lambda) = \frac{\alpha(\lambda)\phi(\lambda)(1-R(\lambda))\,L(\omega,B)^2}{D(\omega,B)^2\,(1-L(\omega,B)^2\,\alpha(\lambda)^2)} \quad (9)$$

Usingtheboundaryconditions(Diengetal.,2007) presentedinEq.(10)and(11),thecoefficients $A(\omega,B)$ and $B(\omega,B)$ aredetermined.

Attheemitter-basejunction(x=0)ofthesolarcell:

$$\left.\frac{\partial\delta(x)}{\partial x}\right|_{x=0} = Sf\,\frac{\delta(0)}{D(\omega)} \quad (10)$$

Attherearsideofthecellbase(x=H):

$$\left.\frac{\partial\delta(x)}{\partial x}\right|_{x=H} = -Sb\,\frac{\delta(H)}{D(\omega)} \quad (11)$$

SfandSbarerespectivelytherecombinationvelocityatthejunctionandattherearsurfaceofthebase.

TherecombinationvelocitySfisimposedbyavaryingimpedanceofanexternalloadandbytheinterfacestatesatthejunction:

Sf=Sf0+Sfm(12)

Indeed,Sf is thesumoftwocontributions:

Sf0istheintrinsicrecombinationvelocity(dependingonlyontheintrinsicparametersofthesolarcellandisinducedbytheshuntresistor),

Sfmreflectstheleakagecurrentinducedbytheexternalloadandfortheoperatingpointofthesolarcell(Dialloetal.,2008;Dèmeetal., 2009).

Photothermalresponse(excesstemperatureacrossthesolarcell):

Whenasolarcellissubjectedtoamultispectralopticalexcitationfromaconstantmodulatedfrequencyandundermagneticfield,theminoritychargecarrier(electrons)is generated inthebase.Themovementofsuchcarriers(diffusionandmigration)inthesolarcellgeneratesaheatfluxandanexcessivetemperaturedifferentfromtheequilibriumtemperatureofthematerial.ForasmalltemperaturechangecomparedtotheinitialtemperatureTo,theheatfluxinthesolarcellcanbedescribedbythisequation:

$$a\cdot\frac{\partial^2\Delta T(x,t,B)}{\partial x^2} + \frac{G_H(x,t,B)}{\rho\cdot c} = \frac{\partial\Delta T(x,t,B)}{\partial t} \quad (13)$$

a Isthethermaldiffusivityofmaterial,ρ thedensityandCitsspecificheat.

ThetermsΔT(x,t,B,)andGH(x,t,B)whichrepresentthechangeintemperaturefromtheinitialtemperatureToandtherateofheatgenerationwithtimewritten:

$$\Delta T(x,t,B) = \Delta T(x,B)\cdot e^{i\cdot\omega\cdot t} \quad (14)$$

$$G_H(x,t,B) = G_H(x,B)^{\pm}e^{i\cdot\omega\cdot t} \quad (15)$$

ΔT(x,B)andGH(x,B)arethespatialcomponentsofthetemperatureandrateofheatgeneration.

Theterm $e^{i\cdot\omega\cdot t}$ representsthetimecomponentofthetemperatureandrateofheatgeneration.

Thistimecomponenthasthesamepulse $\omega = 2\cdot\pi\cdot f$ astheincidentopticalbeamateachtimet.

Equation(13)canberewritten:

$$\frac{\partial^2\Delta T(x,B)}{\partial x^2} - \sigma(\omega)^2\Delta T(x,B) + \frac{G_H(x,B)}{k} = 0 \quad (16)$$

With

k=a.ρ.cisthethermalconductivityofthematerial

$$\sigma(\omega) = \left(\frac{i\cdot\omega}{a}\right)^{1/2}$$

isthecomplexthermaldiffusioncoefficientofthematerial.

ThespatialcomponentGH(x,B)of therateofheat generationisgivenbytheequation:

$$G_H(x,B)=\sum_{\lambda_0}^{\lambda_g}\alpha(\lambda).\phi(\lambda).[1-R(\lambda)]\Delta E(\lambda).e^{-\alpha(\lambda)x}+\frac{E_g.\delta(x)}{\tau}$$

(17)

With E_g is the energy gap of the semiconductor material

$$\Delta E = h.\upsilon - Eg$$

istheenergythermalizationresultingfromtherelaxationofopticallyexcitedcarrierswasduetoabsorptionofphotonsofenergygreaterthantheenergygapEg.

TheheatEquation(13)canbeexpressedas:

$$\frac{d^2\Delta T(x,B)}{dx^2}-\sigma(\omega,B)^2.\Delta T(x,B)=\frac{Eg}{k\tau}\left\{A_1(\omega,B).ch\left(\frac{x}{L_\omega}\right)+A_2(\omega,B).sh\left(\frac{x}{L_\omega}\right)\right\}$$
$$-\sum_{\lambda_0}^{\lambda g}\frac{\alpha(\lambda).\phi(\lambda).[1-R(\lambda)]}{k}\left\{\Delta E+\frac{E_g.L(\omega,B)^2}{D(\omega,B).\tau.(1-\alpha^2.L^2{}_\omega)}\right\}.e^{-\alpha(\lambda).x}$$

(18)

Theexcesstemperatureofthemovementofminoritycarriersinthematerial,solutionoftheaboveequationisoftheform:

$$\Delta T(x,\omega,B,m)=C_1(\omega,B,m).ch(\sigma.x)+C_2(\omega,B,m).sh(\sigma.x)$$
$$+\frac{E_g}{k.\tau.(\sigma(\omega)^2-L(\omega,B)^2)}\left\{A_1(\omega,B,m).ch\left(\frac{x}{L(\omega,B)}\right)+A_2(\omega,B,m).sh\left(\frac{x}{L(\omega,B)}\right)\right\}$$
$$+\sum_{\lambda_0}^{\lambda_g}\frac{\alpha(\lambda).\phi(\lambda).[1-R(\lambda)]}{k.[\sigma(\omega)^2-\alpha(\lambda)^2]}\left\{\Delta E+\frac{E_g.L(\omega,B)^2}{D(\omega,B).\tau[1-\alpha(\lambda)^2.L(\omega,B)^2]}\right\}.e^{-\alpha(\lambda).x}$$

(19)

TheconstantsC1(ω,B,m)andC2(ω,B,m)aredeterminedbythefollowingboundaryconditions:

Attheemitter-basejunction(x=0)

$$\frac{\partial\Delta T\ (x,\omega;B)}{\partial x}\bigg|_{x=0}=Sf\,\frac{Eg\delta(x=0,\omega;B)}{k}\quad(20)$$

Attherearofthebase(x=H):

$$\frac{\partial\Delta T(x,\omega,B)}{\partial x}\bigg|_{x=H}=-Sb\,\frac{Eg\delta\ (\omega,x=H,B)}{k'}\quad(21)$$

II. RESULTS

Photovoltaicresponse(profileofthedensityofminoritycarriercharge):

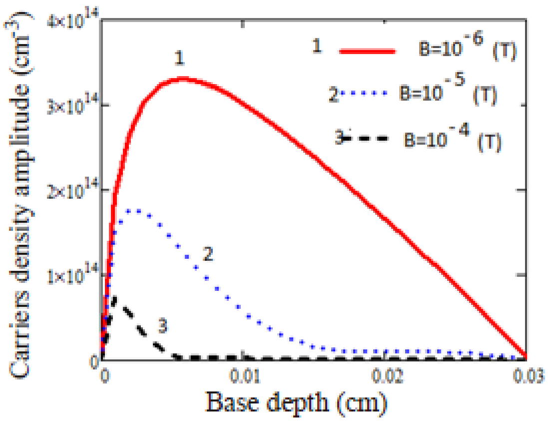

Fig.2Minoritycarrierdensityversusthebasedepthfordifferentvaluesofthemagneticfield.

H=0.03 μ m; D=26cm2/s

Whenthephotovoltaiccellissubjectedtoanillumination,thedensityoftheminoritycarriersincreasesuntilreachingamaximumvaluefromwhichitstartstodecreaseindepth.Wedistinguishthreezones:

- Firstzone:Thegradientofthedensityofthecarriersispositive;thisistranslatedbyapassageoftheminoritycarriersthroughthejunction
- Secondzone:thegradientofthedensityofthecarriersisnull;nocarriersminoritycrossesthejunction:itthereisstorage
- Thirdzone:thegradientofthedensityofthecarriersisnegative,whichtranslatesareductionincrossedminoritycarriersthroughthejunction involvingareductioninthephotocurrent.

Inadditiontothevariationswithdepthxinthebase,theDensityoftheminoritycarriersincreasessignificantlywiththemagneticfield.Moreover,withtheincreaseintheintensityofthemagneticfield,themaximumofdensitymovestowardsthejunction:thatrepresentedastorageofthecarriersclosetothisjunction.Thustheeffectofthemagneticfieldonthephotovoltaiccellsupportsthefastestablishmentoftheopencircuit.

Profileofthecoefficientofdiffusionoftheminoritycarriersinexcess

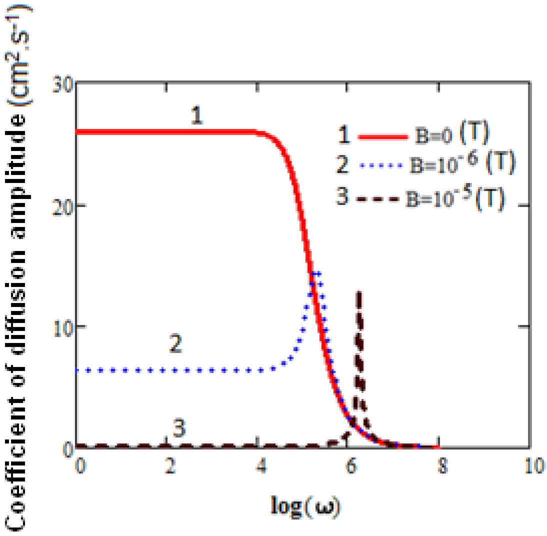

Fig.3:Moduleofthecoefficientofdiffusionaccordingtothelogarithmofthepulsationforvariousvaluesofthemagneticfield H:0.03 μ m;D:26cm^2/s

Intheabsenceofmagneticfieldappliedtothephotovoltaiccelli.e.B=0,onedistinguishestwozonesonthecurveobtained:

- afirstzoneintheintervalofpulsation[0rad/s;2.10^{4}rad/s]inwhichthecomplexcoefficientofdiffusionremainspracticallyconstant(quasi-static mode)
- secondzoneintheinterval[2.10^{4}rad/s;10^{8}rad/s[inwhichthecomplexcoefficientofdiffusiondecreaseclearly(strongfrequencyresponseofmodulation)

Theapplicationofamagneticfield,makesleaveathirdzonewherethecoefficientofdiffusionincreaseinaremarkablewayuntilobtainingofa peak:itisthephenomenonofresonance.Thislastisobtainedwhenthefrequencyofmodulationis equaltothefrequencycyclotron(frequencyofthe electrononitsorbitinthepresenceofamagneticfield)which,initsturn,isalinearfunctionofthe intensityofthemagneticfieldapplied

Photothermicanswer(profileofthetemperaturevariation)

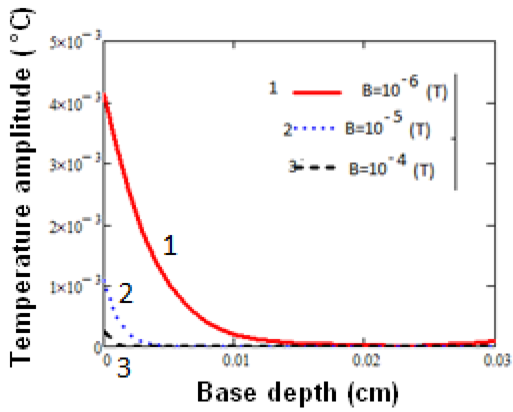

Fig.4:Moduleofthetemperaturevariationaccordingtodepthxinthebasefordifferentvaluefromthemagneticfield

Thecurvesoffigure4showthatthetemperaturevariationdecreaseswiththedepthofthebase.Itis maximum with the junction. Ineed,closetothejunction,theshortwavelengthsofthespectrumofsolarradiationusefulofsilicon,absorptiveinvolveanimportantgenerationofcarrierswithgreat energies(higherthantheenergyofthegapof silicon). Thesestrongsurplusenergiesofthecarriersphotogeneratedclosetothejunctionarelostbythermalization;whatjustifiesthehighvalueoftheexcessoftemperatureobservedtothejunctionofthephotovoltaiccell.Inaddition,insituationofshortcircuit,thejunctionistheplaceofconvergenceof carriers ofloadphotogeneratedinsidethebaseofthephotovoltaiccell. Itresultsthepresencefromitfromahighnumberofcarriersintheareaclosetothejunctionandconsequentlyanumberofhighshocksourceofanimportantheatemissionthusofanimportantexcessoftemperature.Andjustlikethedensityofminoritycarriersofload,thetemperaturevariationisstronglyinfluencedbytheintensityofthemagneticfieldclosetothejunction.

Profileofthetemperaturevariationaccording tothespeedofrecombination to the junction

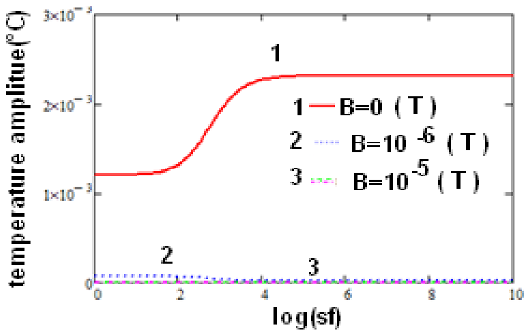

Fig.5:Moduleofthetemperaturevariationaccordingtothespeedofrecombinationtothejunctionforvariousvaluesofthemagneticfield.D=26cm2/sH=0.03µm,a=1cm^2/s,k'=1,54W/cm.°C

Thecurvesofthefigureshowthatthetemperaturewiththejunctionofthephotovoltaiccellisanincreasingfunctionthespeedofrecombination tothejunctionforagivenpulsation.The temperaturevariesslightlywiththelowvaluesthespeedofrecombinationtothejunction.Then,itincreasesgraduallyandreachesitsmaximumwith thegreatvaluesthespeedofrecombinationtothejunctioni.e.in short-cicuit.Theapplicationofthemagneticfielddecreasestheamplitudeofthetemperaturevariation.Indeed,withtheintensityofthemagneticfield,themaximumofdensitymovestowardsthejunction.

Thuswiththegreatvaluesthespeedofrecombinationtothejunction,thetemperaturevariationdecreaseconsiderably.

Profileofthedensityflux

Theexpressionofthedensityfluxofheatisgivenbythefollowingrelation:

$$\phi(x,\omega,B,m) = -k\frac{\partial \Delta T(x,\omega,B,m)}{\partial x}$$

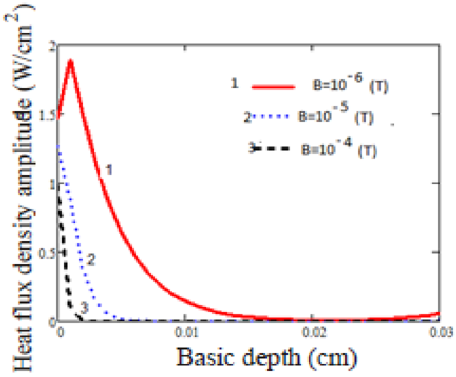

Fig.6:Moduleofthedensityofheatfluxasafunctionofdepthfordifferentva- luesofthemagneticfield**D=26cm2/s,H=0.03µm,a=1cm2/s,k=1,54W/cm.°C)**Thedensityfluxofheattakesthesameformasthetemperaturevariation.Indeed,itismaximum withthejunctionof-thephotovoltaiccellandisa decreasingfunctiondepthofthebaseandangular pulsationofthesignal.

Justlikethedensityoftheminoritycarriers,thedensityfluxofheatincreasessignificantlywiththemagneticfieldbecauseofthestorageoftheminoritycarriersofloadclosetothejunction. Inadditionitsamplitudedecreaseswiththeintensityofthe magnetic field. Thebehaviorofthechargecarriersdescribeddecreasesatthetimeofthestudyofthevariationinthetemperaturemakesitpossibletoalsoexplaintheshapeofthecurvesofdensityfluxthermal.

Profileofthethermalimpedance

Theexpressionofthethermalimpedanceisgivenbythefollowing relation

$$Z(x,\omega,B,m) = \frac{\Delta T(x,\omega,B,m)}{\phi(x,\omega,B,m)}$$

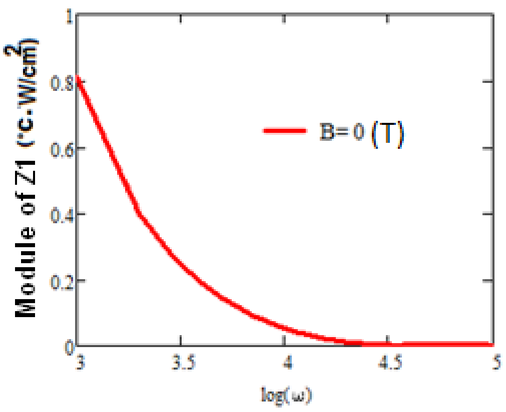

Fig.7:Moduleofthethermalimpedanceaccordingtothelogarithmofthepulsationforanullmagneticfield

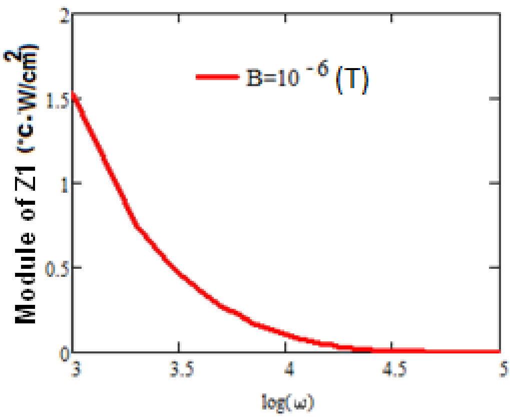

Fig.8:Moduleofthethermalimpedanceaccordingtothelogarithmofthepulsationinthepresenceofthemagneticfield

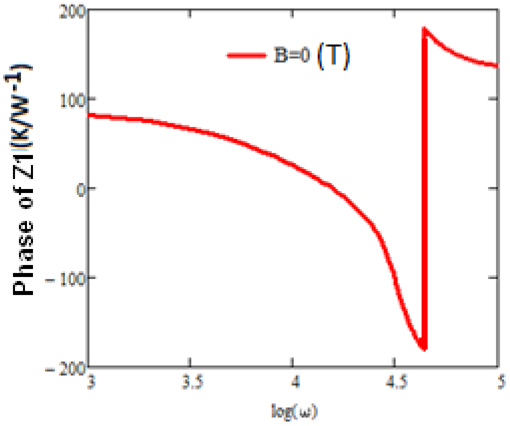

Fig.10:Phaseofthethermalimpedanceaccordingtothelogarithmofthepulsationwithoutmagneticfield(D=26cm2/scm/sH=0.03µm,a=1cm^2/s,k=1,54W/cm.°C)

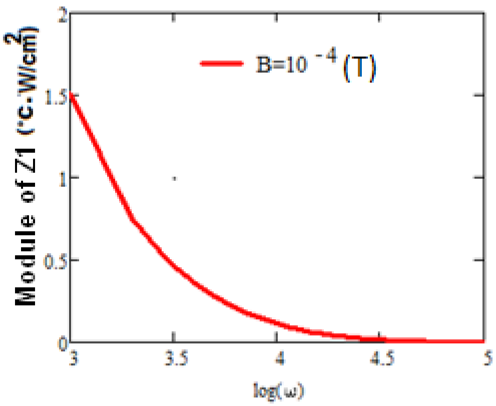

Fig.9:Moduleofthethermalimpedanceaccordingtothelogarithmofthepulsationinthepresenceofthemagneticfield

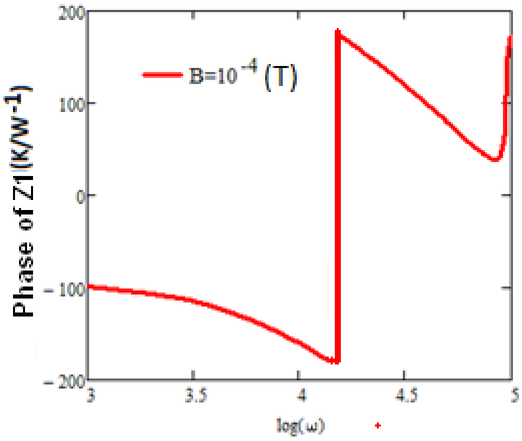

Fig.11:Phaseofthethermalimpedanceaccordingtothelogarithmofthepulsationinthepresenceofamagneticfield(D=26cm2/scm/sH=0.03µm,a=1cm^2/s,k=1,54W/cm.°C)

Thecurvesoffigures 7, 8and9showthat the moduleofthethermalimpedanceisadecreasing function of the pulsation. Theincreaseinthepulsation involvesareductioninthedensityoftheminority carriersandconsequentlyareductioninthe temperature.In this field, the capacitive effects appear there.

Moreo-ver,theapplicationofthemagneticfieldincreasesthevalueofthe moduleoftheimpedance.One can note that in the vicinity of resonances i.e.forfrequencieslowerorequalto resonanc-es,thediffusionoftheminoritycarriersiscarriedoutinaconsiderablewayandthathaslike corollaryalightreductionintheimpedance.

DiagramofBodeoftheimpedanceforanilluminationbythefrontface:phaseofzph

$$\varphi(x,\omega,B,m) = \arg(Zph(x,\omega,B,m))$$

$\varphi(x,\omega,B,m)$ Is the phaseofthethermal Impedance

Intheabsenceofmagneticfield(fig.10),whenthepulsationislowerthan10^4Hz,thephaseofthethermalimpedanceisalmostconstant.

Forthepulsationsrangingbetween10^4Hzand$10^{4.5}$Hz,thephasedecreaseandremainsnegative;inthisfieldthecapacitiveeffectsoverridetheinductiveeffects.Forthefrequencieshigher than104.5Hz,thephaseincreasesandremainsalwaysnegative;inthisfieldtheinductiveeffects overridethecapacitiveeffects.

The applicationofthemagneticfield(fig.11),watchthat:

Forthebeachesofthepulsationgoingof10^3Hzwith$10^{4.2}$Hz,thecapacitiveeffectsoverridetheinductiveeffects;

When thepulsationisequalto$10^{4.2}$Hz, thephaseincreasesquickly,inthiscasetheinductiveeffectsoverridethecapacitiveeffects.

Forthevaluesofthe pulsation ranging Be-tween$10^{4.2}$Hzand10^5Hz,thephasedecreaseandremainspositive,inthisfieldthecapacitiveeffectsoverridetheinductiveeffects.Andbeyond10^5Hz,thephaseincreasesandremainsalwayspositive,infacttheinductiveeffectsoverridethecapacitiveeffects.Thus onecannotethatthemagneticfieldsupportsafastalternationofthepredominanceofthecapacitiveandinductiveeffects.

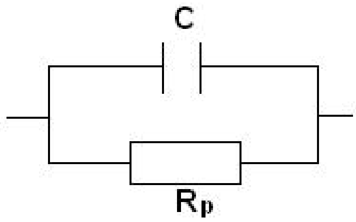

Fig.12Circuitareequivalentofthethermalimpedancewithoutmagneticfieldapplied

Thediagramoffigure12representstheequivalentelectricalcircuitwhichcharacterizestheeffectsobservedstartingfromthediagramsofBode(fig7.8and9).CisthecapacityandRPparallelresistance

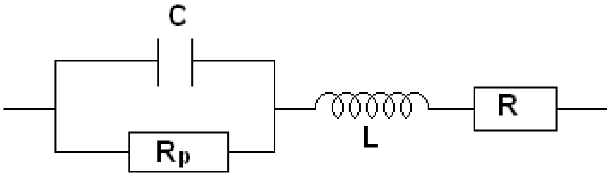

Fig.13:Circuitareequivalentofthethermalimpedancewithmagneticfieldapplied

Theelectricalcircuitrepresenteddescribesthetwophenomenacapacitiveandinductiveoftheimpedance(figure10and11)whereCisthecapacityandRPparallelresistance.

III. CONCLUSION

Theresolutionoftheequationofcontinuityoftheminoritycarriersinthebaseofthephotovoltaiccell,allowedthestudyofcertainphenomenologicalandelectricparametersaccordingtothefrequencyofmodulationandtheeffectofthemagneticfield.Adegradationoftheintrinsicpropertiesofthephotovoltaiccell, through thesevariousparameters,wasnoted.Thankstotheuseofphenomenologicalparameterslikespeedsofrecombinationtothejunction,thebehaviorofthe photovoltaiccellcanbestudiedthroughthedensityofthecarriers,theexcessoftemperaturecomparedtothetemperatureofbalanceofmaterial andthedensityfluxofheat. ThediagramsofBodeofthethermalimpedancemadeitpossibletoestablishtheequivalentcircuitofthephotovoltaiccellundermultispectral illuminationandtheeffectofthemagneticfield.

NOMENCLATURE

B(Tesla)Intensityofthemagneticfieldω(rad.s^{-1})Angularfrequency D_n^* (cm2.s-1)Coefficientofdiffusionoftheminoritycarriersinthebase
D*(cm2.s-1)Complexcoefficientofdiffusion
δ(cm3)Densityofthephotominoritycarrierscreatedinthebaseaccordingtodepthxandoftimet
G(x,t)(cm-3.s1)Rateofgenerationaccordingtodepthxandtimet
gε(x)(cm-3.s-1)Rateofgenerationaccordingtodepthx
H(µm)Thicknessofthebase L_n^* (cm)Diffusionlenghtoftheminoritycarriersinthebase L_ω^* (cm)Complexdiffusionlenghtoftheminoritycarriersinthebase accordingtothefrequencyωandofthemagneticfieldK(λ)Constantintheexpressionofthedensityof thecarriers
λ_g thewavelengthofcutofthesemiconductorestimatedat1,12µm
$\lambda_0$theminimalwavelengthofthesourceoflightisequalto0,3µm
α(λ)(cm-1)Absorptioncoefficienttothewavelengthλ
R(λ)Coefficientofreflectionofmaterialtothewavelengthλ
To(°C)initialtemperatureofthephotovoltaiccell
ΔT(°C)temperaturevariation
Z(°C/W)thermalimpedance
Φ(λ)(cm-2/s)Incidentalflow
k(W/cm/°C)thermalconductivity
Φ(W/cm2)isthedensityfluxofheat
Eg(ev)energyofgapofsilicon
$\sigma(\omega)$ Thermalcoefficientofdiffusionprocess
ρ (g/dm3)Densityofvolumeofsilicon
C(J/g/°C)Specificheatofsilicon

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