



Gallium Nitride based Metal-Semiconductor-Metal UV Photodetectors

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Outline

- Why III-nitride semiconductors?
- Metal-semiconductor-metal photodetectors
- Semiconductor Equations
- Comsol Model
- Interdigitated electrodes with corrugations
- Results and Conclusions

The Periodic Table

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu			
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr			

Image source: <http://www.chemcool.com>

Semiconductors

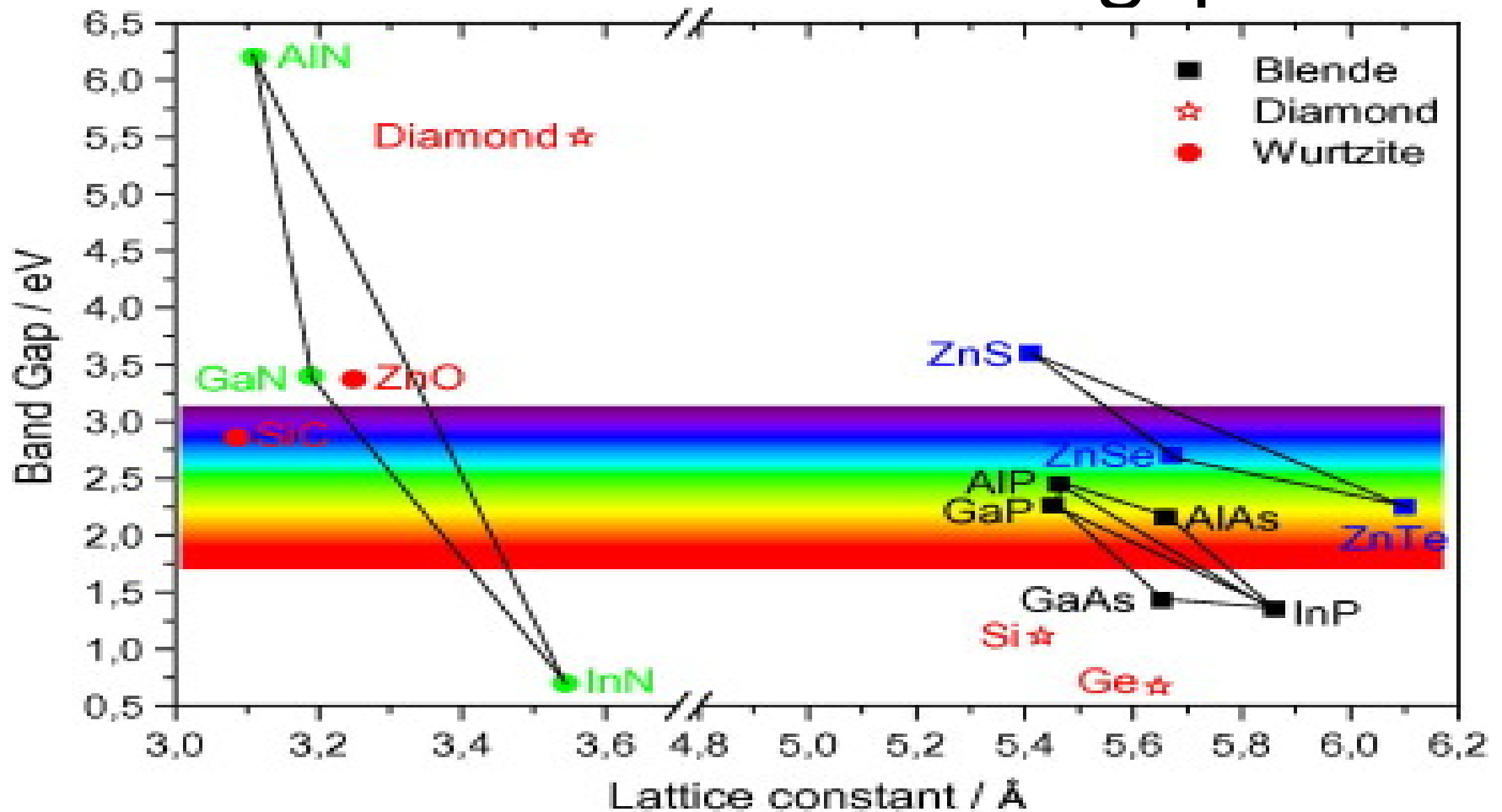
<i>Group II</i>	<i>Group III</i>	<i>Group IV</i>	<i>Group V</i>	<i>Group VI</i>
	B Boron 5	C Carbon 6	N Nitrogen 7	O Oxygen 8
Mg Magnesium 12	Al Aluminium 13	Si Silicon 14	P Phosphorus 15	S Sulphur 16
Zn Zinc 30	Ga Gallium 31	Ge Germanium 32	As Arsenic 33	Se Selenium 34
Cd Cadmium 48	In Indium 49	Sn Tin 50	Sb Antimony 51	Te Tellurium 52
Hg Mercury 80	Tl Thallium 81			

III-V

II-VI

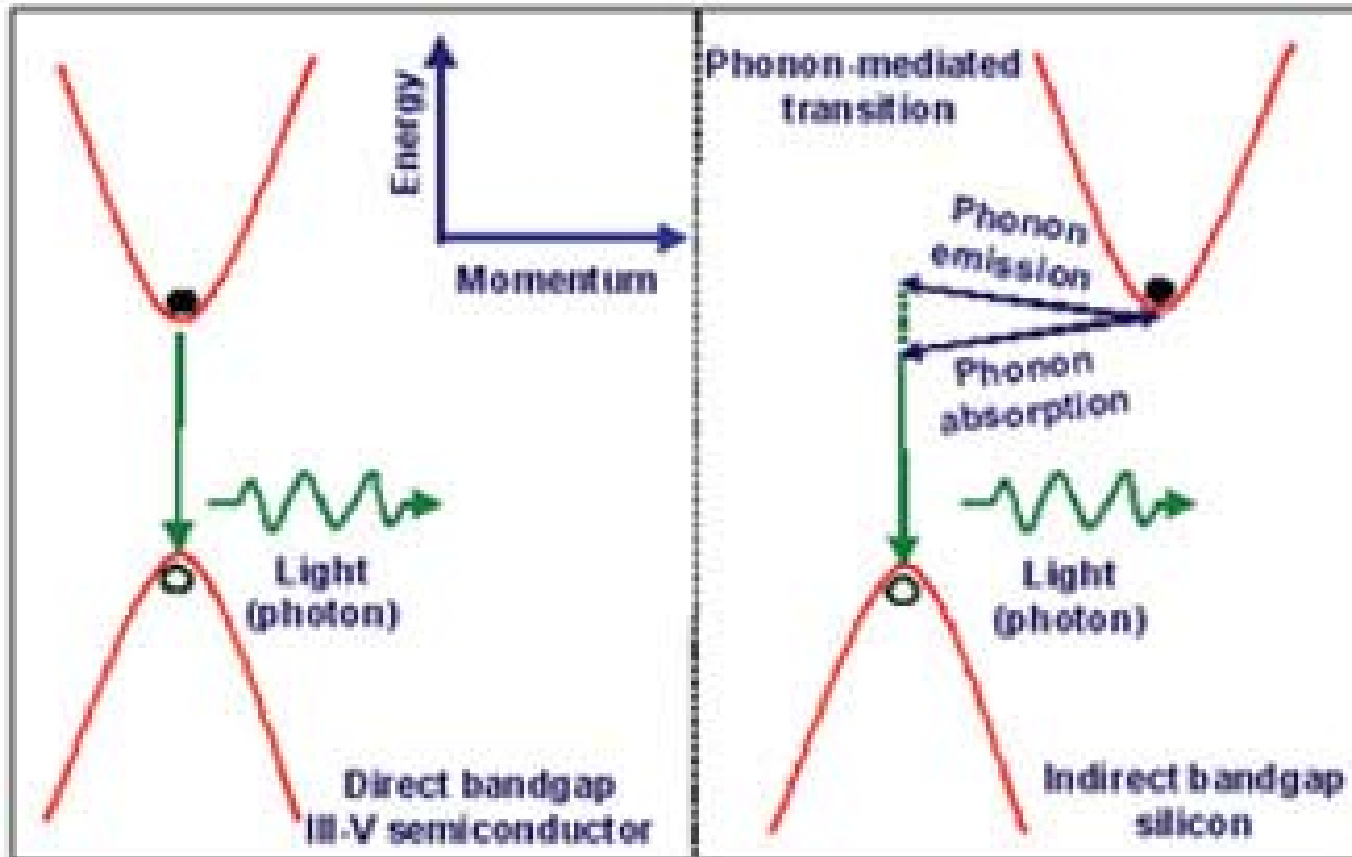
Image source: <http://www.iue.tuwien.ac.at/phd/palankovski/node18.html>

Semiconductor Bandgap



Ref: Ugo Lafont et al, "Increasing the reliability of solid state lighting system via self-healing approaches: A review", Microelectronic Reliability 52(2012) 71-89

Direct and Indirect Bandgap



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UV Photodetector Applications

Flame detectors

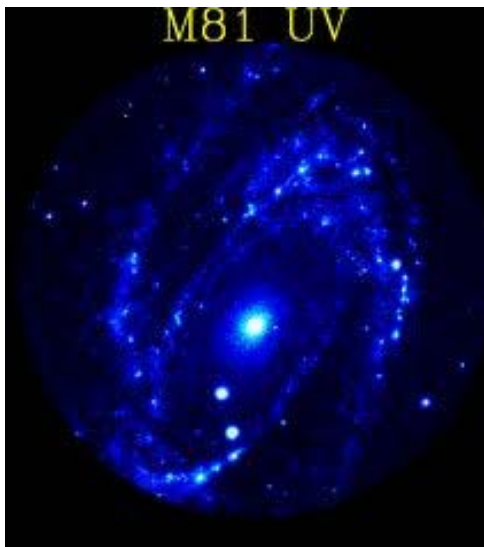


Ozone layer monitoring

Hole in the Ozone Layer?



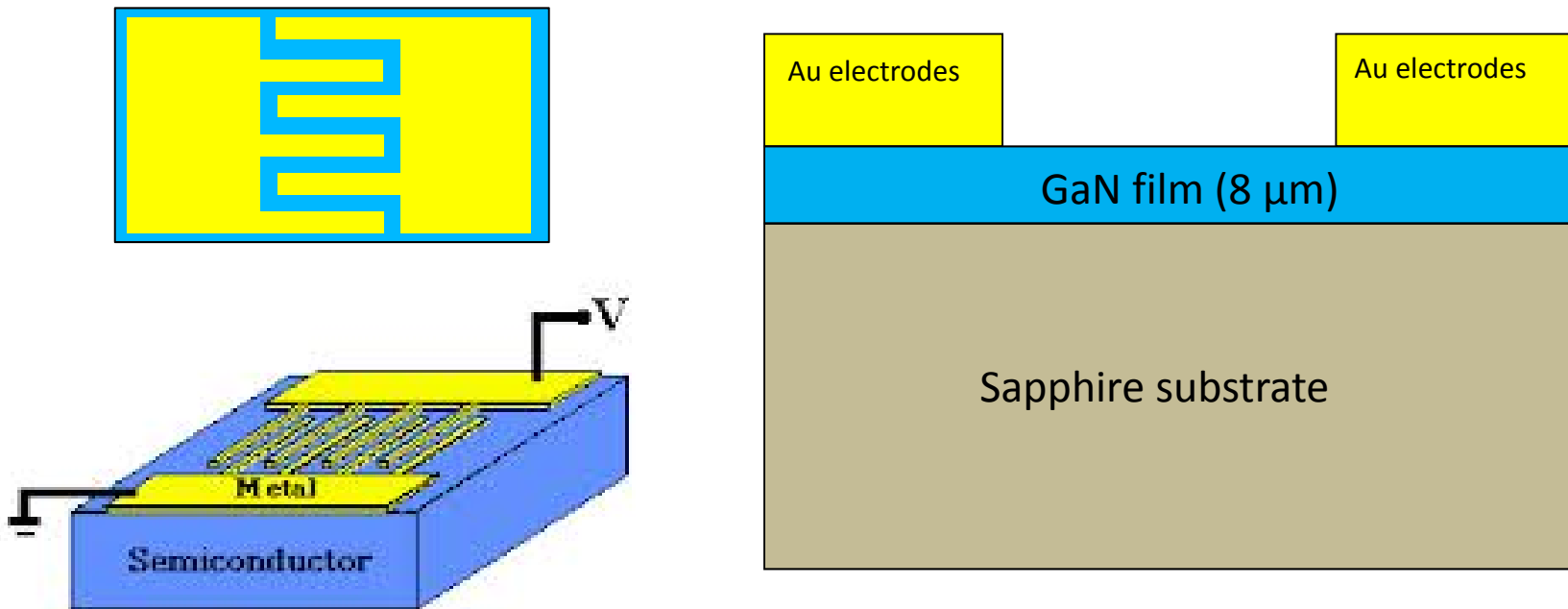
UV astronomy



Pollution monitoring



Metal-semiconductor-metal photodetector structure



MSM photodetector advantages:

- Ease of fabrication
- Inherently low capacitance
- Greater receiver sensitivity

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Semiconductor Equations

- Poisson's Equation

Required	$\nabla \cdot (\nabla V) = -q(p - n + ND^+ - NA^-)$
Comsol	$\nabla \cdot (\nabla V) = -q(p - n + ND^+ - NA^-)$

Semiconductor Equations

- Continuity Equation

Required	$\frac{\partial n}{\partial t} = \frac{1}{q} \nabla \cdot J_n - U_n + G_n$ $\frac{\partial p}{\partial t} = \frac{1}{q} \nabla \cdot J_p - U_p + G_p$
Comsol	$\frac{\partial n}{\partial t} = \frac{1}{q} \nabla \cdot J_n - U_n$ $\frac{\partial p}{\partial t} = \frac{1}{q} \nabla \cdot J_p - U_p$

$$\phi = \phi_0 \exp[-\alpha(z - z_0)]$$

$$G = \alpha \phi$$

$$G = \alpha \phi_0 \exp[-\alpha(z - z_0)]$$

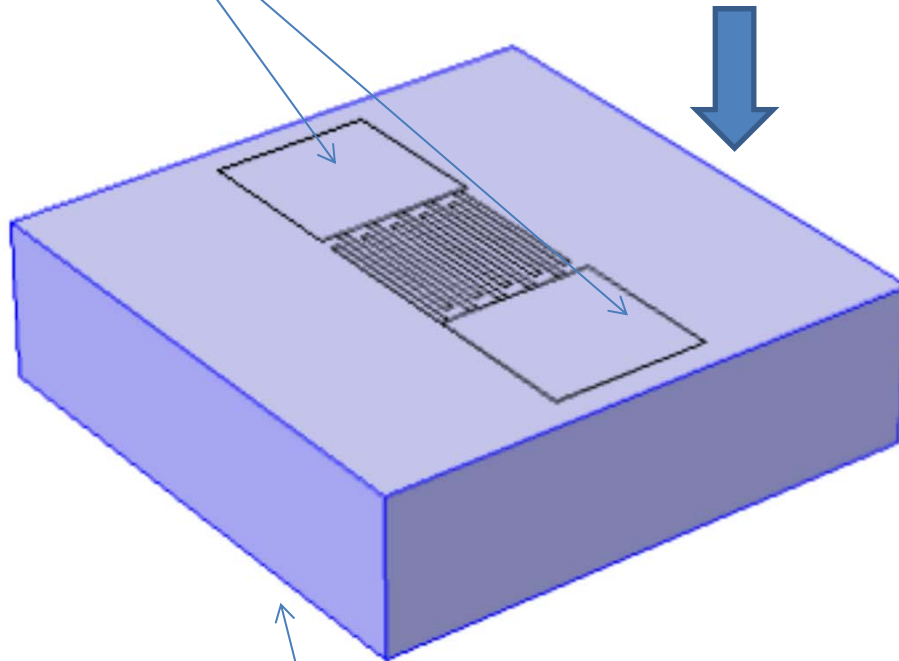
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Comsol Model

Electrodes (Schottky contacts)

Illumination



GaN active layer

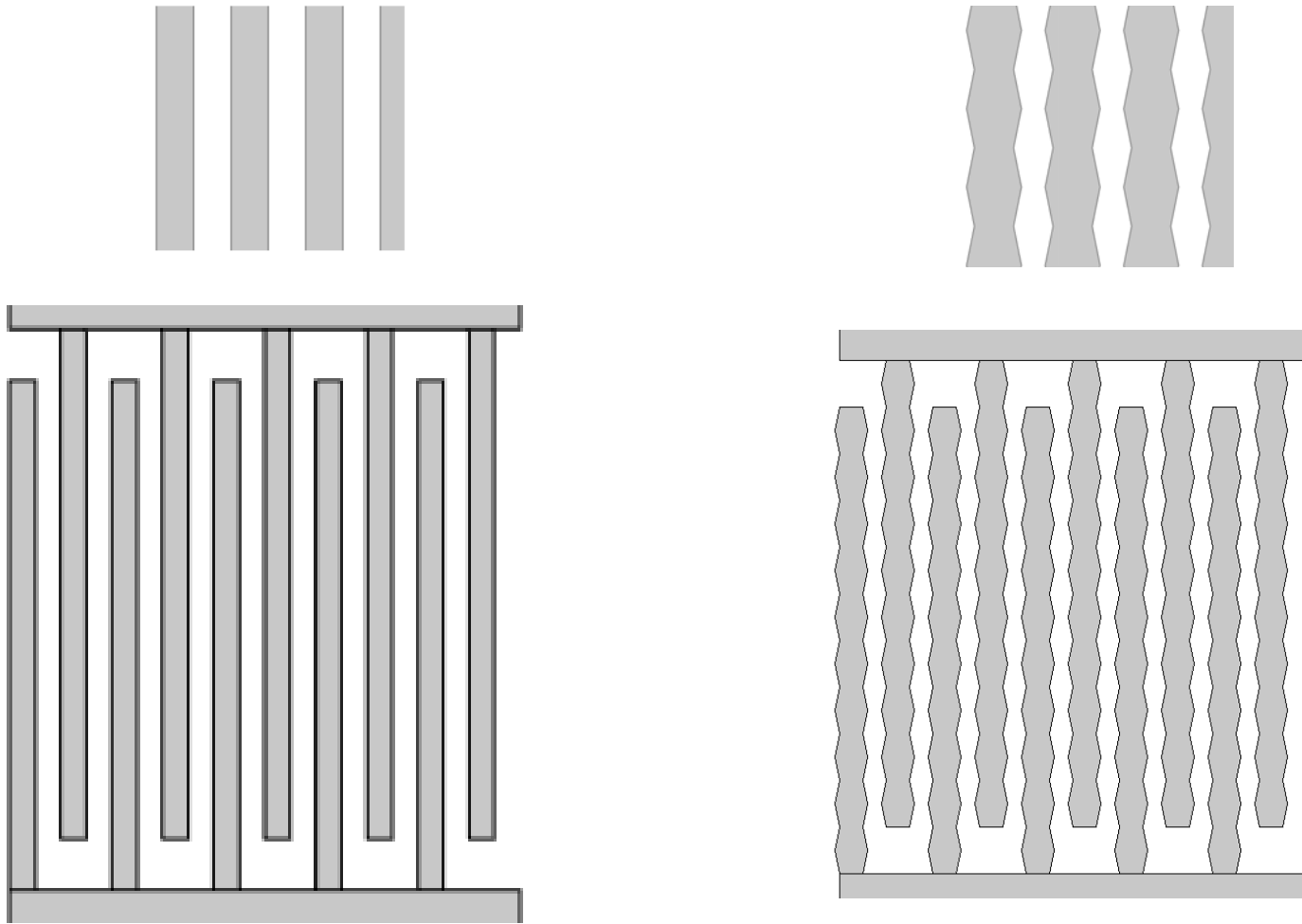
- ▶ Geometry 1
- ▶ Materials
- ▶ Semiconductor (*semi*)
 - ▶ Semiconductor Material Model 1
 - ▶ Insulation 1
 - ▶ Zero Charge 1
 - ▶ Continuity/Heterojunction 1
 - ▶ Initial Values 1
 - ▶ Metal Contact 1
 - ▶ Metal Contact 2
 - ▶ Semiconductor Doping Model 1
 - ▶ Weak Contribution 1
 - ▶ Weak Contribution 2
- ▶ Equation View
- ▶ Mesh 1
- ▶ Study 1
 - ▶ Parametric Sweep
 - ▶ Step 1: Stationary
 - ▶ Solver Configurations
- ▶ Results
 - ▶ Data Sets
 - ▶ Derived Values
 - ▶ Tables

Weak contribution node added to account for optical generation of electrons and holes

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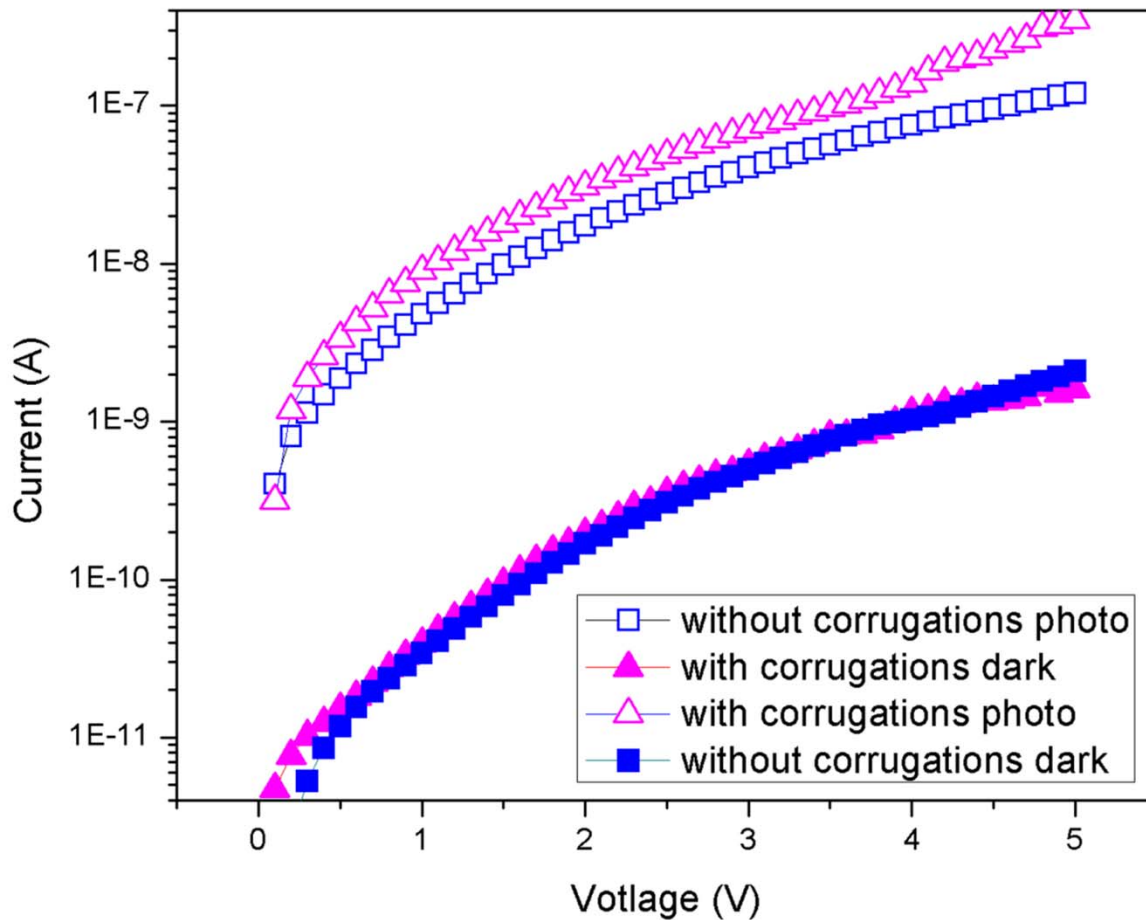
Corrugated Interdigitated Electrodes



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Photoresponse



- Increase in photoresponse!
- No free lunch!
 - $R \uparrow$ RC delay \uparrow
- Circular interdigitated electrodes?
 - $C \downarrow$ RC delay \downarrow

Conclusions

- GaN based MSM photodetector modelled
- Photoresponse properties improved by using corrugated interdigitated electrodes
- Semiconductor module to be coupled with RF module in the future to sweep over incident frequencies



