CoolCAD Electronics, LLC
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Engineering Executive and LLC Member
Overview of Technology

• CoolCAD has three major technology areas:
  1. Silicon Carbide Based Electronics Design, Fabrication and Development:
  2. Computer Aided Electronics Design Software
  3. Electronics Product Design and Prototyping
• **CoolCAD Electronics, LLC**
  • 5000 College Avenue, Suite 2103,
    College Park, MD 20740
  • www.coolcadcadelectronics.com

• Established: 2006
• Employees: 16
• Revenue 2014: $1.4 million
  – (90% Government; 10% Private)
• Type of Business: LLC
Focus of Presentation: Technology Area 1
Silicon Carbide Based Electronics Design, Fabrication and Development

Funding Agency: NASA

– Design and Fabrication of Deep Ultra Violet Optical Sensors: Photodiodes and Avalanche Photodiodes

– TRL level: 6

– Uniqueness:
  • Uses new Silicon Carbide wide bandgap semiconductor:
  • Sees Deep UV, does not get confused with visible.
  • Extremely low noise levels
  • Proprietary SiC semiconductor fabrication processes developed.
Avalanche Photodiode Background

- Avalanche Photodiodes are capable of converting deep Ultra Violet photons to a measurable current source:

UV Photons

SiC Deep UV Avalanche Photodiode Detector:
Counts single photon

Photon Current to Voltage Converter

Detected Photons
Device Design and Simulation

- Self Consistent solution of DD equations. Provides carrier concentrations, current and electric field.
- Novel design shows field enhancement which will be used to separate e-h pairs.
- Graded doping will be designed with modeling to provide optimal fields for e-h pair separation.
- Developed physics based solvers to determine electrostatic potential and carrier concentration in SiC APDs.

![Graphs showing SiC APD I-V calculations](image)

SiC APD I-V calculations for APDs with varying concentrations of doping, optical power, and surface doping gradient. Gains of the curves corresponding to the high optical power are shown on the right.
General Process Steps for Fabrication of APD

- Selective coverage of surface using photoresist/metal
- Reactive ion etching to expose desired surfaces
- Sacrificial Oxidation to passivate the surface
- Growth of thermal oxide/deposition
- Metal Deposition using electron beam deposition

Cross Section View of APD device

Sample SRIM/TRIM simulation for dopant profiling
Process Design and Manufacturing

• Fabrication Process Steps:

Figures show a series of processing steps of the Silicon Carbide Avalanche Photo Diodes. Starting with SiC Wafer with Epitaxial Layers followed by patterning, etching, oxidation, passivation, metallization, contacting and annealing.
Product Results

- Our design, simulation and fabrication process have produced a marketable product with low leakage current, high responsivity to deep UV photons.

Fig 1: (a) Chip after wire bonding, (b) breakdown curves of Avalanche Photo Diodes (APDs), (c) Optical response APD.
Current Technology Status and Next Steps to Commercializing:

- Chip Fabrication and Process Flow Standardized at Prototype Level
- Volume production at wafer level is ready for implementation.
- Chip packaging needs to be perfected

Cost to advance this technology

- Approx. $150K: Labor, Materials & Facilities

Why should NASA, Industry, and other government agencies invest?

This is a new technology based on the wide bandgap semiconductor: SiC.

Utilizing SiC allows for the realization of the next generation in UV spectroscopy and Power Electronics.

It will allow for much more efficient, smaller and lighter weight electronics and instrumentation.

Applications for NASA, DOD, DOE, Healthcare, Manufacturing, etc.
Target Market Applications of UV Detector:

- **NASA**: applications in UV Spectroscopy and Dual use for Ion detection. Will reduce weight & power requirements of spacecraft. Especially suitable for cube-sat applications.
- **DOD**: Early warning sensors for incoming rockets. Highly sensitive, low noise UV light from significant distances
- **Public Health**: Monitoring UV exposure of individuals for potential over-exposure in high UV environments.
- **Sanitation**: UV Detection for microbe sterilization with UV light. Part of a UV Source-Detector combination.
- **Manufacturing**: Surface defect detection. UV camera may see cracks and defects that are not observable under visible or infrared light.
- **Environment, Climate**: Effect of UV absorption or lack thereof by atmosphere or ozone layer.
Facilities

Manufacturing and Testing Facilities

• In House Semiconductor Processing:
  – Thermal Oxidation
  – Ion Activation
  – Rapid Thermal Annealing
  – Metal Contact Silicide

• Members of UMD Mtech:
  – Allows for convenient rental of state of the art micro and nanofab at close proximity.

• State of the Art Optical and Electronics Testing Facility:
  – Probe Station, Cryostat, RF, Microelectronic Test Equipment
  – High voltage, high current testing
  – Optical UV and IR Benches
Core Competencies

1. Silicon Carbide (Wide Bandgap) Based Electronics
   a. Design Fabrication and Development:
   b. Deep UV Photodetectors
   c. 21st Century Power Electronics Devices
   d. Sponsors: NASA, ARL

2. Computer Aided Electronics Design Software
   a. Circuit Modeling for Si and SiC based systems
   b. Sponsors: OSD, NASA, ARL

3. Electronics Product Design and Prototyping:
Core Technical Competencies: Sensor Design & Fab

Infrared Rectenna
(DARPA, NSF, NAVY)

Uncooled high resolution IR Imaging
Threat Detection (Missiles, Rifle fire)
Extremely wide band detectors
Terahertz communication

200nm UV Avalanche Photodiode
(NASA)

Structure 1
1. N- : 0.5 micron
2. P+ : 0.5-1.0 micron
3. N- Substrate

Structure 3
1. N+ : 0.1 micron
2. N- : 0.5 micron
3. P+ : 0.5-1.0 micron
4. N- Substrate

Solar blind EUV Detectors for monitoring atmospheric ozone & air pollution
Solar flare monitoring
Pathogen detection
Flame detection in jet engines
Non-line of sight UV communications
Core Tech Competencies: CAD Tool Development

CoolSPICE Circuit Simulator
(NASA)

SiC Power System Design
(ARL)

Cryogenic Modeling and Test Chip Design

SiC Physical Modeling → SiC Device Design

Device Characterization →

SiC DMOSFET Compact Model

Power Circuits Design → Passive Models

Circuit Simulation

Electrical Parasitics Simulation → Thermal Simulation

Packaging, Wire Bonding and Layout

Optimized Design?

Revise Designs based on Thermal and Inductive Effects

Fabricate System and Validate SiC Power System Design Platform

T = 4K
Human Algometer
(Children’s National Medical Center)

UVA+B Bracelet
(Sensor Sensor LLC)

ECOSENSE: Energy Monitoring
(MIPS)

SiC Power Converter
(ARL and MIPS)

Chip Design
(NASA)
Contacts

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