An Autonomous Institute
Affiliated to VTU, Belagavi
Approved by AICTE, New Delhi
Recognized by UGC under 2(f) & 12 (B)

REPORT

"Recent advancements in GaN-based semiconductor devices for next-generation high-frequency and high-power applications such as 6G and e-vehicles: A technology in the spotlight"

Date: December 02 – 14, 2024

Institute Name: MVJ College of Engineering, Bangalore

AICTE TRAINING AND LEARNING ACADEMY, PUNE

An Advanced Faculty Development Programme (FDP) titled "**Recent advancements in GaN-based semiconductor devices for next-generation high-frequency and high-power applications such as 6G and e-vehicles: A technology in the spotlight**" *sponsored by AICTE training and Learning (ATAL) Academy* was organized by the Department of Electronics and Communication Engineering. The programme was held from December 2nd to 14th, 2024, in Seminar Hall-4, from 9:30 am to 5:00pm. The event was presided by Principal, **Dr Ajayan K R,** Dean- Affiliation & Accreditation, **Dr. M. Brindha, and** the Programme Coordinator, Professor **Dr. Remashan Kariyadan.** The resource persons for the programme were:

1. **Dr. Roy Paily Palathinkal**, Professor, IIT Guwahati
2. **Mr. Chandrasekhar Kypa,** Vice President & Business Leader, Quest Global, Bangalore
3. **Dr. Biplab Sarkar,** Associate professor, IIT Roorkee
4. **Dr. Apurba Laha,** Professor, IIT Bombay
5. **Mr. Sudhakar Reddy Amireddy,** Senior Manager, Intel Corporation, Bangalore
6. **Dr. G N Ratna,** Principal Research Scientist, IISc., Bangalore
7. **Dr. R. Selvakumar**, Senior Engineer, Cadence Design Systems, Bangalore
8. **Dr. V Suresh Babu,** Former Principal, MVJ college of Engineering, Bangalore

Dr. Roy Paily Palathinkal (Professor, IIT Guwahati)

Education:

- Ph. D., IIT Madras, 2004
- M. Tech, IIT, Kanpur, 1996
- B. Tech, College of Engineering Trivandrum, 1990

Experience:

- Professor (Higher Administrative Grade) in Dept. of EEE, IIT Guwahati, from 28-12-2021.
- Professor in Dept. of EEE, IIT Guwahati from 21-04-2012.
- Associate Professor in Dept. of ECE, IIT Guwahati, from 09-08-2007 to 20-04-2012.
- Assistant Professor in Dept. of ECE, IIT Guwahati from 22-07-2004 to 08-08-2007.
- Senior Design Engineer in Magnetic Head Division of Hard Disk Drive Unit at JTS Technology, from 13-03-1996 to 15-03-1999.
- Lecturer at ECE Department SAK Engineering College, University of Bombay, from 12-2-1992 to 23-07-1994.

Mr. Chandrasekhar Kypa (Vice President & Business Leader, Quest Global, Bangalore)

Education:

- M.S. (Software Systems) BITS Pilani, 2003
- Sr. Management Program from IIIM Calcutta, 2014
- PGDBM, XIME Bangalore, 2004

Experience:

- 25+ Years of experience in VLSI Design
- Worked with esteemed organizations like Infineon Technologies, AMD, Philips Semiconductors and Synopsys.

Dr. V Suresh Babu (Former Principal, MVJ College of Engineering, Bangalore)

Education:

- B.Tech., TKM College of Engineering, University of Kerala, 1988
- M.Tech., IIT Madras, 1996
- Ph.D., College of Engineering, Trivandrum, 2013

Experience:

- He worked at various positions in College of Engineering Trivandrum, Government College of Engineering, Kannur, Government College of Engineering, Idukki, Government College of Engineering Barton Hill and Government College of Engineering, Wayanad.

Dr. Biplab Sarkar (Associate Professor, IIT Roorkee)

Education:

- Ph. D., NC State University, 2015
- M. Tech., IIT Bombay, 2012
- B. Tech., NERIST, 2010

Experience:

- Associate Professor, IIT Roorkee, from March 2024
- Assistant Professor, IIT Roorkee, from Dec 2018 to Feb 2024
- Assistant Professor, IIT (ISM) Dhanbad, from Nov 2017 to Dec 2018

Dr. Apurba Laha (Professor, IIT Bombay)

Education:

- Ph. D., Indian Institute of Science, Bangalore, 2004
- M. Sc., Jadavpur University, Kolkata, 1999

Experience:

- Professor, Department of Electrical Engineering, IIT Bombay, from July 2019
- Associate Professor, Department of Electrical Engineering, IIT Bombay from September 2014 to June 2019
- Assistant Professor, Department of Electrical Engineering, IIT Bombay from January 2012 to August 2014
- Research Staff, Institute of Electronic Materials and Devices (MBE), Leibniz University, Hannover, Germany from January 2007 to December 2011
- Alexander von Humboldt Research Fellow, Institute of Electronic Materials and Devices (MBE), Leibniz University, Hannover, Germany from May 2005 to December 2006

Mr. Sudhakar Reddy Amireddy (Sr. Manager, Intel Corporation, Bangalore)

Education:

- M. Tech., IIT Madras

Experience:

- 25+ years of experience of delivering several generations of server CPU/GPU/Chipset/Wireless/Wireline products and EDA tool development/Design flows.
- He worked at Mentor Graphics, NXP, Infineon and IBM.

Dr. G N Ratna (Principal Research Scientist, IISc., Bangalore)

Education:

- Ph.D., Indian Institute of Science, 1998
- M. E., Indian Institute of Science, 1990
- B. E., Indian Institute of Science, 1982

Experience:

- Principal Research Scientist, Electrical Engineering, IISc., Bangalore from 1999 to 2024

Dr. R. Selvakumar (Senior Engineer, Cadence Design Systems, Bangalore)

Education:

- Ph.D., Anna University, 2016
- M. E, Karunya Institute of Technology, Coimbatore
- B.E., MVJ College of Engineering, 2001

Experience:

- 20+ years of experience in the field of FPGA and VLSI.
- He worked at Synopsys and CoreEL technologies, Bangalore.

The schedule for the Faculty Development Programme is provided below.

MVJ COLLEGE OF ENGINEERING Since 1982

PROGRAMME SCHEDULE WEEK 1

DAY 1 02-12-2024	DAY 2 03-12-2024	DAY 3 04-12-2024	DAY 4 05-12-2024	DAY 5 06-12-2024	DAY 6 07-12-2024
09:00 AM to 09:30 AM Inauguration					
9:30 AM – 12:00 PM Session 1 Compound Semiconductors Dr. Roy Paily Palathinkal, Professor, IIT Guwahati	9:30 AM – 12:00 PM Session 3 Basics of GaN High Electron mobility transistors Mr. Sudhakar Reddy Amireddy, Sr. Manager, GPU IP Validation, Intel Corporation, Bangalore	9:30 AM – 12:00 PM Session 5 GaN HEMT Power Devices Dr. Biplab Sarkar, Associate Professor, IIT Roorkee	9:30 AM – 12:00 PM Session 7 6G Communications Dr. G N Ratna, Principal Research Scientist, IISc., Bangalore	9:30 AM – 12:00 PM Session 9 GaN HEMT Devices, Fabrication & challenges Dr. Apurba Laha, Professor, IIT Bombay	9:30 AM – 12:00 PM Session 12 High Frequency GaN-HEMT devices Dr. V Suresh Babu, Advisor, MVJ College of Engineering
12:00 PM – 01:00 PM Article Discussion	12:00 PM – 01:00 PM Article Discussion	12:00 PM – 01:00 PM Article Discussion	12:00 PM – 01:00 PM Article Discussion		12:00 PM – 01:00 PM Article Summary
1:00 PM to 1:30 PM LUNCH				12:00 PM to 12:30 PM LUNCH	1:00 PM to 1:30 PM LUNCH
1:30 PM – 04:00 PM Session 2 Compound Semiconductor Devices Dr. Roy Paily Palathinkal, Professor, IIT Guwahati	1:30 PM – 04:00 PM Session 4 GaN HEMTs on Si substrates Mr. Sudhakar Reddy Amireddy, Sr. Manager, GPU IP Validation, Intel Corporation, Bangalore	1:30 PM – 04:00 PM Session 6 High Frequency GaN-HEMT devices Dr. Biplab Sarkar, Associate Professor, IIT Roorkee	1:30 PM – 04:00 PM Session 8 GaN Devices & Circuit simulation Mr. Chandrasekhar Kypa, Vice President & Business Leader, Quest Global, Bangalore	12:30 PM – 03:00 PM Session 10 High-frequency & High-power applications of HEMTs: 6G & e-vehicles Dr. Apurba Laha, Professor, IIT Bombay	1:30 PM – 04:00 PM Session 13 GaN devices & IC design Mr. Chandrasekhar Kypa, Vice President & Business Leader, Quest Global, Bangalore
04:00 PM – 05:00 PM Article Discussion	04:00 PM – 05:00 PM Article Discussion	04:00 PM – 05:00 PM Article Discussion	04:00 PM – 05:00 PM Article Discussion	03:00 PM to 05:30 PM Session 11 GaN HEMT devices Dr. V Suresh Babu, Advisor, MVJ College of Engineering	04:00 PM – 05:00 PM Article Summary

The schedule for the Faculty Development Programme is provided below (contd.)

MVJ COLLEGE OF ENGINEERING Since 1982

PROGRAMME SCHEDULE WEEK 2

DAY 7 09-12-2024	DAY 8 10-12-2024	DAY 9 11-12-2024	DAY 10 12-12-2024	DAY 11 13-12-2024	DAY 12 14-12-2024
9:00 AM – 12:30 PM Session 14 **Research Methodology** **Dr. G N Ratna, Principal Research Scientist, IISc., Bangalore**					9:30 AM – 01:30 PM **Team-Wise Presentation of the output**
12:30 PM to 01:00 PM **LUNCH**					**01:30 PM to 02:00 PM** **LUNCH**
1:00 PM – 03:30 PM Session 15 **GaN HEMTs for 6G & e-vehicles** **Dr. R Selvakumar, Senior Principal Solutions Engineer, Cadence Design Systems, Bangalore**	9:30 AM – 05:00 PM **Industrial Visit** **Centre for Nano Science and Engineering, Indian Institute of Science (IISc.), Bangalore**	9:30 AM – 05:00 PM **Industrial Visit** **Samsung Semiconductor India Research (SSIR), Bangalore**	9:30 AM – 05:00 PM **Industrial Visit** **Intel Technology (India) Pvt. Ltd., Bangalore**	9:30 AM – 05:00 PM **Industrial Visit** **Quest Global, Bangalore**	02:00 PM – 03:00 PM **Reflection Journal**
					03:00 PM – 04:00 PM **Feedback**
3:30 PM – 06:00 PM Session 16 **Sustainable GaN semiconductor technology beyond Silicon** **Dr. R Selvakumar, Senior Principal Solutions Engineer, Cadence Design Systems, Bangalore**					04:00 PM – 05:00 PM **Valedictory Session**

Inauguration Session:

The Faculty Development Programme was inaugurated by **Dr. Roy Paily Palathinkal**, Professor at IIT Guwahati on 2nd December, 2024 at 10.00 am with the lighting of the lamp. The Principal of the institute, **Dr Ajayan K R**, addressed the participants and congratulated them on registering for this FDP. A total of **40** participants - faculty members from the host institution, faculty from other colleges, and professionals from the industry - participated in the Faculty Development Programme.

Dr. Roy Paily Palathinkal, Professor, IIT Guwahati inaugurating the Faculty Development Programme by lighting the lamp (Dr Ajayan K R, Principal, MVJ College of Engineering can be seen in the picture)

The list of participants is as follows:

S. No	Name of the Participant	Email ID	Contact Number	College Name
1	Mrs. Padmavathi M	padmavathim-ece@dayanandasagar.edu	9535198302	Dayananda Sagar college
2	Dr. G BENI	beni@niuniv.com	9443858177	Noorul Islam Centre for Higher Education
3	Mrs. VARSHA HOTUR	varsha.hotur@gmail.com	9986076577	M V J COLLEGE OF ENGINEERING
4	Dr. shima ramesh maniyath	shima.ramesh@mvjce.edu.in	8197884463	M V J COLLEGE OF ENGINEERING
5	Mrs. Anu Joy	anujoy@mvjce.edu.in	9632220616	MVJ COLLEGE OF ENGINEERING
6	Mrs. SHEHER BANU S	s.sheher@gmail.com	9739636466	MVJ COLLEGE OF ENGINEERING
7	Mr. L DAVID WILLIAM RAJ	davidraj1311@gmail.com	9790347191	MVJ COLLEGE OF ENGINEERING
8	Dr. NIJA K S	nijaks_ece@mvjce.edu.in	8848563541	MVJ COLLEGE OF ENGINEERING
9	Mr. Jayanth C	sjayjayanth@gmail.com	9900490755	Dayananda Sagar College of Engineering
10	Dr. Rajesh Saha	rajeshsaha_ece@mvjce.edu.in	9759794625	MVJ COLLEGE OF ENGINEERING
11	Mr. P SATHEESH KUMAR	satheeshkumar.p@cit.edu.in	9789130028	BMS INSTITUTE OF TECHNOLOGY
12	Mr. SANTHOSH KUMAR R	santhosh-ece@dayanandasagar.edu	9632984759	DSCE
13	Dr. DRUVA KUMAR S	druva-ece@dayanandasagar.edu	7760975555	DAYANANDA SAGAR COLLEGE OF ENGINEERING
14	Dr. Anitha V R	anithavr@gmail.com	9949400700	BMS Institute of Technology and Management
15	Mr. PRAKASH V	venthanash1038@gmail.com	9487393963	VIJAYA VITTALA INSTITUTE OF TECHNOLOGY
16	Dr. Leena k	leenarenjith@gmail.com	7760676245	Vijaya Vittala Institute of Technology
17	Miss Swetha Rani M	swetharanim12@gmail.com	9845454006	VVIT
18	Mrs. SREEKANTHAM HIMA BINDU	shimabindu411@gmail.com	9676166193	VVIT
19	Mrs. KUSUMA S SALANKE	salankekusumas@gmail.com	9110838471	Vijaya VIttala Institute of Technology

20	Mr. Vijaykumar S	vijay.mys.vk@gmail.com	8618627450	MVJ COLLEGE OF ENGINEERING
21	Dr. Rabaya Basori	rabeya.phy@gmail.com	8348346502	MVJ COLLEGE OF ENGINEERING
22	Miss SHRUTHI N	shruthingowda48@gmail.com	8147975802	MVJ COLLEGE OF ENGINEERING
23	Mrs. Divya J	divyaj811@gmail.com	9164958199	MVJ COLLEGE OF ENGINEERING
24	Mrs. Shilpa Hiremath	shilpasharankh@bmsit.in	8884611668	BMSIT&M
25	Miss Britney Naomi Mannas	britneymannas@gmail.com	7619663332	Quest global
26	Mr. Kumar P	kumar-ece@dayanandasagar.edu	8050565568	Dayananda Sagar College of Engineering
27	Miss suranya k	suranyak96@gmail.com	9846517831	MVJ COLLEGE OF ENGINEERING
28	Dr. Shenbagalakshmi V	shenbagalakshmi_ece@mvjce.edu.in	9791321118	MVJ COLLEGE OF ENGINEERING
29	Miss M Poornima	poornima_ece@mvjce.edu.in	9611193321	MVJ COLLEGE OF ENGINEERING
30	Miss nithyashree s	nithyashree.26@gmail.com	8123963980	Dr.Ambedkar Institute of Technology
31	Mr. karthik s	s.karthik014@gmail.com	7406577043	ACHARYA INSTITUTE OF TECHNOLOGY
32	Mr. Nishchinth T N	devangnishchinth@gmail.com	8277922910	Qualcomm
33	Mr. Ritesh Belgudri	ritesh.belgudri@gmail.com	9964865457	NA
34	Mr. Mahboob ul Haque	mahboob.vlsi@gmail.com	7259460647	Maulana Azad National Urdu University, Polytechnic - Bangalore
35	Mr. Ajaykumar D	ajaykumard.intn@bmsce.ac.in	8951238944	BMS College of Engineering, Bangalore
36	Dr. SWAPNIL SHANTARAM NINAWE	swapnil.ninawe@gmail.com	9535145712	Dayananda Sagar College of Engineering
37	Mrs. Dr. Pavithra G	dr.pavithrag.8984@gmail.com	9591071967	Dayananda Sagar College of Engineering
38	Mrs. panthagani srilakshmi	srilakshmip.cs@hkbk.edu.in	6363534951	HKBK college of engineering
39	Dr. Namita	namita_ece@mvjce.edu.in	7779984453	MVJ COLLEGE OF ENGINEERING
40	Dr. Nandhini V L	sunandi7276@gmail.com	9741190311	Govt. SKSJTI

Day 01 (02-12-2024) - Session 1 - "Compound Semiconductors" | Dr. Roy Paily Palathinkal, Professor, IIT Guwahati

Dr. Ajayan K R, Principal of MVJ College of Engineering, Bangalore welcoming the chief guest Dr. Roy Paily Palathinkal, Professor at IIT Guwahati with a bouquet.

Dr. Roy Paily Palathinkal began his presentation by highlighting the importance of semiconducting materials in the modern world. He noted that for Si-based devices, the current production technology node is 3 nm, with major semiconductor companies working on developing the 2 nm technology node. He mentioned that while the semiconductor business is risky, it remains highly profitable. Additionally, he pointed out that the semiconductor industry relies on countries like Japan and South Korea for silicon wafers, chemicals, and other essential materials.

Dr. Roy also highlighted the advantages of the compound semiconductor material GaN in comparison to silicon, explaining why GaN is ideal for high-voltage, high-power, and high-speed applications.

The resource person, Dr. Roy Paily Palathinkal, delivering a session on "Compound Semiconductors"

Day 01 (02-12-2024) - Session 2 - "Compound Semiconductor Devices" | Dr. Roy Paily Palathinkal, Professor, IIT Guwahati

In the afternoon session, Dr. Roy discussed important switching device parameters, such as the on/off current ratio and subthreshold slope. He highlighted that beyond CMOS devices, emerging technologies are based on compound semiconductors. Dr. Roy elaborated on devices made from SiC and GaN materials. He emphasized that GaN-based devices, such as HEMT devices, are promising candidates for high-power and high-frequency applications. These devices are particularly suitable for realizing low-noise amplifiers, which are essential for cell phone base stations.

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Dr. Roy Paily Palathinkal with a memento.

A group photo of participants with the resource person Dr. Roy Paily Palathinkal

Day 02 (03-12-24) - Session 3 -"Basics of GaN High Electron Mobility Transistors" - Mr. Sudhakar Reddy Amireddy, Sr Manager, Intel Corporation, Bangalore

Dr. Shrinivas L Gombi, Dean of Academics, MVJ College of Engineering, Bangalore welcoming the chief guest Mr. Sudhakar Reddy, Sr Manager, Intel Corporation, Bangalore with a bouquet.

Mr. Sudhakar Reddy began his talk by comparing the material properties of GaN with Si and SiC, explaining why GaN is a better choice for realizing high-power and high-speed applications. This is possible because of the high bandgap and the 2DEG (two-dimensional electron gas) feature present in AlGaN/GaN-based heterostructure systems. He also discussed the material parameters that influence the 2DEG carrier concentration and its mobility. Compared to depletion-mode HEMTs (High Electron Mobility Transistors), enhancement-mode transistors are preferred because depletion-mode transistors require both positive and negative power supplies, whereas enhancement-mode devices require only a single power supply.

The resource person, Mr. Sudhakar Reddy, delivering a session on "Basics of GaN High Electron Mobility Transistors"

The Resource person, Mr. Sudhakar Reddy, delivering a session on "Basics of GaN High Electron Mobility Transistors"

Day 02 (03-12-24) - Session 4 -"GaN HEMTs on Si substrates" - Mr. Sudhakar Reddy Amireddy, Sr Manager, Intel Corporation, Bangalore

Mr. Sudhakar Reddy, in the afternoon session, talked about fasciation of HEMT devices on Si substrates. He listed major processing steps involved in the fabrication of these devices. One reason why GaN HEMTs on silicon substrates are required because then Si CMOS devices and GaN HEMTs can be integrated on silicon substrates.

One domain when GaN HEMTs will find wide applications is in data centers. Low voltage GaN devices are fabricated.

The company 'episil" located in Taiwan is producing 6 inch & 8 inch GaN/Si epitaxy wafers to develop 100-600 V devices. The company "GaN Systems" (now Infineon) produces GaN power transistors with

both 100V and 650V GaN FETs shipping in volume.

GaN power devices are currently used in consumer and industrial applications, such as AC adapters and server power supplies. TSMC supports GaN technology for its potential environmental benefits in automotive applications, such as on-board chargers and inverters for electric vehicles (EVs).

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Mr. Sudhakar Reddy with a memento.

A group photo of participants with the resource person Mr. Sudhakar Reddy, Sr Manager, Intel Corporation, Bangalore

Day 03 (04-12-24) - Session 5 - "GaN HEMT Power Devices" | Dr. Biplab Sarkar, Associate Professor, IIT Roorkee

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore welcoming the chief guest Dr. Biplab Sarkar, Associate Professor, IIT Roorkee with a bouquet.

Dr. Biplab Sarkar started the session with the material properties of Si, Ge and compound semiconductors. Power devices are used in different voltage ranges such as low-voltage, medium-voltage and high-voltage ranges. GaN-based converters are preferred to Si-based converters because GaN-based converters are faster. On-resistance (Ron) is an important parameter of a power device. The on-resistance is inversely proportional to band-gap. If breakdown voltage increases, the on-resistance also increases. The only way to improve Ron versus breakdown voltage is to play with critical electric field and the critical electric field is directly related to band-gap. This shows that stepping into wider bandgap materials is the only choice.

The resource person, Dr. Biplab Sarkar, delivering a session on "GaN HEMT Power Devices"

Day 03 (04-12-24) - Session 6 - "High-frequency HEMT Devices" | Dr. Biplab Sarkar, Associate Professor, IIT Roorkee

In the afternoon session, Dr, Biplab Sarkar focused on high-frequency (high-speed) devices. GaN power amplifiers are popular because of their high-power delivery capacity. He hinted that GaN devices will form the heart of 5G and 6G communication systems. GaN HEMTs are better than InP HEMTs and GaAs HEMTs. GaN HEMT devices use T-shaped gate structure.

The resource person, Dr. Biplab Sarkar, delivering a session on "GaN HEMT Power Devices"

He concluded that future research into wide bandgap devices for both power and RF devices will remain fruitful.

An FDP participant (Dr.Nandhini, Assistant Professor, Govt. SKSJTI, Bangalore) honoring the chief guest Dr. Biplab Sarkar, with a memento.

A group photo of participants with the resource person Dr. Biplab Sarkar, Associate Professor, IIT Roorkee

Day 04 (05-12-24) - Session 7 - "6G Communications" | Dr. G N Ratna, Principal Scientist, IISc Bangalore

Dr. A C Niranjanappa, Dean (Research), MVJ College of Engineering, Bangalore welcoming the chief guest Dr. G N Ratna, IISc., Bangalore with a bouquet.

Dr. Ratna started the session with the characteristics of 5G and talked on the drawbacks of 5G network. Then she brought in 6G, which is the sixth-generation wireless technology, set to revolutionize connectivity with unprecedented speeds (6G is 100x faster than 5G), ultra-low latency (Latency as low as 10 microseconds), and AI integration. The low latency as low as 10 microseconds would enable real-time applications like tactile internet (remote surgery.

6G will explore terahertz spectrum (0.1 THz to 10 THz), providing enormous bandwidth but requiring new technologies for signal generation, transmission, and reception.

As 6G networks aim to deliver ultra-high-speed data, low latency, and massive device connectivity, GaN technology is positioned to play a critical role in enabling the hardware required to meet these ambitious goals. GaN's properties make it an ideal material for high-frequency, high-power, and high-efficiency applications, which are essential for 6G networks.

Gallium Nitride is a wide-bandgap semiconductor material that has unique electrical and thermal properties, making it highly suitable for high-performance devices in high-power and high-frequency applications.

GaN transistors and amplifiers are expected to play a critical role in enabling communication at the terahertz frequencies (100 GHz to 10 THz), which are a core aspect of 6G. At these high frequencies, GaN-based devices can provide the power and efficiency needed for signal transmission, overcoming the inherent challenges such as signal attenuation and power loss.

For 6G base stations, GaN-based power amplifiers (PAs) are vital to handling the high power demands of transmitting over long distances at high frequencies.

Dr. Ratna concluded the session by stating that Gallium Nitride (GaN) devices will play a pivotal role in the evolution of 6G networks, driving advancements in high-frequency communication, low-latency performance, and energy efficiency.

The resource person, Dr. Ratna, delivering a session on "6G Communications"

The resource person, Dr. Ratna, delivering a session on "6G Communications"

Dr. Shima Ramesh Maniyath, Head, Electronics and Communications Engineering Department, MVJ College of Engineering, honoring the chief guest Dr. Ratna with a memento.

A group photo of participants with the resource person Dr. Ratna, Research Scientist, IISc., Bangalore

Day 04 (05-12-24) - Session 8 - "GaN Devices & Circuit simulation" | Mr. Chandrasekhar Kypa, Vice President & Business Leader, Quest Global, Bangalore

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Mr. Chandrasekhar Kypa with a Bouquet

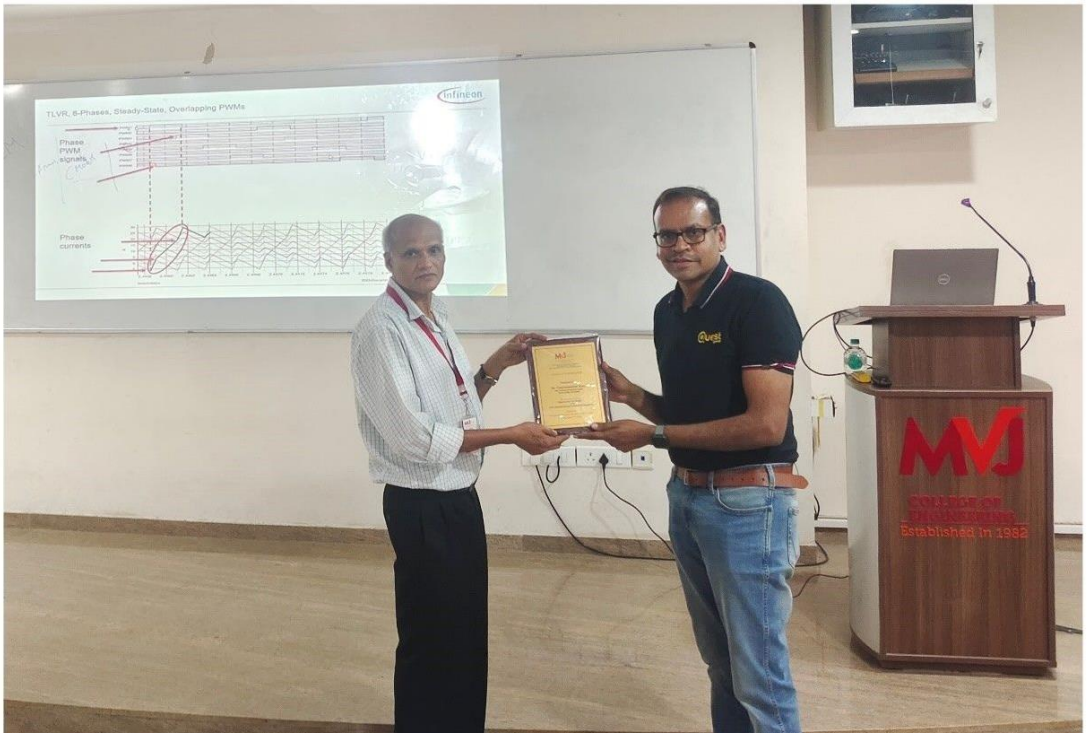
Mr. Chandrasekhar Kypa began the session by providing an overview of the various technology nodes in silicon technology and mentioned that the current technology node in production is 3 nm. Since silicon devices face challenges in handling high-power and high-frequency applications, devices based on GaN (Gallium Nitride) are gaining significance in 6G communications and electric vehicles (EVs).

The resource person, Mr. Chandrasekher Kypa delivering a talk on 'GaN Devices & Circuit simulation'

He also mentioned various applications of GaN devices. GaN transistors switch much faster than silicon MOSFETs, offering the potential for lower switching losses. These devices can be used in a wide range of applications, including telecommunications, servers, motor drives, laptop adapters, and on-board chargers for electric vehicles.

He commented that *simulation* is a key tool for evaluating the performance of a system before fabricating it. He also mentioned PLECS (Piecewise Linear Electrical Circuit Simulation), which is specifically designed for simulating power electronics systems. This includes power converters (DC/DC, DC/AC, AC/DC, etc.), inverters, rectifiers, and motor drives.

Mr. Chandrasekhar Kypa explained about '**Twin Builder',** a simulation software tool developed by 'Ansys'. This tool focuses on creating and deploying **digital twins**. A **digital twin** is a virtual model that accurately represents a physical system, allowing users to simulate, monitor, and optimize the behavior of that system in real time. Twin Builder is particularly useful for industries such as manufacturing, automotive, aerospace, energy, and more.



Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore welcoming the chief guest Mr. Chandrasekhar Kypa, with a Memento

End of day 4 Afternoon session with the resource person Mr. Chandrasekhar Kypa, Quest Global, Bangalore

Day 05 (06-12-24) - Session 9 - "GaN HEMT Devices, Fabrication & Challenges" | Dr. Apurba Laha, Professor, IIT, Bombay

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore welcoming the chief guest Dr. Apurba Laha, with a bouquet

Dr. Apurba Laha began his talk by emphasizing the importance of GaN (Gallium Nitride) material in power devices. According to a report, the number electronic gadgets is nearly 2.0 billion and each gadget wastes approx. 5 watts of power per day at the adaptor (during conversion). This leads to daily power wastage is nearly 10 gigawatts, and this loss is due to power conversion inefficiencies. This serious issue can be addressed by replacing silicon-based power convers by GaN-based power converters as the efficiency of GaN-based power converters is approximately 95.98%, which is significantly higher than that of Si-based (Silicon-based) power converters.

He emphasized the importance of crystallinity at the interface between the AlGaN/GaN heterostructure, as it affects the mobility and electron concentration in a 2-DEG. According to the speaker, the 2-DEG is the heart of a HEMT device.

Large area single crystal GaN substrates is not available yet, therefore the primary challenge is the growth of high quality GaN on foreign substrate. India imports most of its epitaxial wafer from United

States, Japan, and Russia.

The resource person, Dr. Apurba Laha delivering a talk on ‘GaN HEMT Devices, Fabrication & Challenges

Day 05 (06-12-24) - Session 10 - “High-frequency & High-power applications of HEMTs: 6G & e- vehicles” | Dr. Apurba Laha, Professor, IIT, Bombay

`

Dr. Apurba Laha continued the afternoon session by highlighting the role of GaN HEMT devices in high-frequency and high-power applications.

GaN HEMT devices possess high electron mobility, and therefore, these devices are suitable for high-frequency (high-speed) applications. Such devices are essential for 6G technologies."

GaN has a larger bandgap, which leads to a higher breakdown voltage. This means that GaN devices can operate at high voltages in the range of 400–800V. This property can be utilized in EV charging infrastructure. In addition, GaN has lower on-resistance, which means it has lower conduction losses and higher efficiency. This property makes GaN-based devices suitable for DC-DC converters."

He concluded his session with a note that there is huge potential for start-ups in the GaN technology field, both in terms of producing GaN wafers and GaN HEMT devices."

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Dr. Apurba Laha with a memento

End of session-10 on day 5 with the resource person Dr. Apurba Laha, IIT Bombay

Day 05 (06-12-24) - Session 11 - “GaN HEMT devices” | Dr. V Suresh Babu, Former Principal, MVJ College of Engineering)

Dr. Shima Ramesh Maniyath (Head, Electronics and Communications engineering department) welcoming the chief guest Dr. Suresh Babu with a bouquet

Dr. Suresh Babu started his presentation by posing the important question: what makes GaN an attractive material compared to the widely used semiconducting material, silicon? He then, discussed the important material properties of GaN and the formation of the 2-DEG in heterostructure devices. In the case of HEMT devices, both the 2-DEG concentration and mobility are critical.

He elaborated on the parameters that affect mobility in general, as well as how 2-DEG formation in AlGaN/GaN heterostructures differs from that in AlGaAs/GaAs heterostructure systems. He also emphasized the importance of spontaneous and piezoelectric polarization in GaN HEMT devices.

The resource person, Dr. Suresh Babu delivering a talk on ‘GaN HEMT Devices’

Day 06 (07-12-24) - Session 12 - "High Frequency GaN HEMT devices" | Dr. V Suresh Babu, Former Principal, MVJ College of Engineering)

In this session, Dr. Suresh Babu, said that GaN HEMT devices are used in high-frequency, high-power, and low-noise applications. The speaker, then, described what are properties these devices should have so that they can be utilized for these applications.

He concluded the session with a note that there is a good potential for these devices to find applications in future 6G and e-vehicle applications.

Dr. Suresh Babu delivering a talk on 'High Frequency GaN HEMT devices

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Fr. Suresh Babu with a memento

End of session-12 on day 6 with the resource person Dr. Suresh Babu (Former principal, MVJ College of Engineering, Bangalore)

Day 06 (07-12-24) - Session 13 - “GaN devices & IC design” | Mr. Chandrasekhar Kypa, Vice-President & Business Leader, Quest Global, Bangalore

Dr. *M* Brindha, Professor, MVJ College of Engineering, Bangalore honoring the chief guest, Mr. Chandrasekhar Kypa with a bouquet

In today's presentation, **Mr. Chandraseker Kypa** started with the typical IC realization

flow and then moved on to GaN common circuits. In the chip implementation flow, the speaker described various stages, namely: System Level**,** Register Transfer Level**,** Gate Level**,** Transistor Level**,** Layout Level**,** and Mask Level**.**

In the second part, **Mr. Chandraseker Kypa** explained the design aspects of two GaN circuits: GaN onboard charging circuit and the Traction Inverter with an optional boost converter. The speaker also elaborated on the custom design flow and the semi-custom design flow. The speaker also explained the key aspects of Helium + Palladium co-simulation.

The resource person, Mr. Chandrasekhar Kypa delivering a talk on 'GaN devices & IC design"

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore honoring the chief guest Mr. Chandrasekhar Kypa with a memento

End of session-13 on day 6 with the resource person Mr. Chandrasekhar Kypa

Day 07 (09-12-24) - Session 14 - “Research Methodology” | Dr. G N Ratna, Principal Scientist, IISc Bangalore

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, Bangalore welcoming the chief guest Dr. Ratna, with a bouquet

Dr. Ratna first explained the meaning of "Research Methodology." It refers to the systematic process, techniques, and tools used to conduct research, analyze data, and draw conclusions.

The speaker then described the key components of Research Methodology with suitable examples in detail: Research Design, Research Approach, Research Methods, Data Collection, Data Analysis, Ethical Considerations, Research Tools, and Documentation and Reporting.

The resource person, Dr. Ratna delivering a talk on “Research Methodology”

Dr. Shima Ramesh, HOD-ECE MVJ College of Engineering, Bangalore honoring the chief guest, Dr. Ratna G N with a memento

End of session-14 on day 6 with the resource person, Dr Ratna

Day 07 (09-12-24) - Session 15 - “GaN HEMTs for 6G & e-vehicles” | Dr. R Selvakumar, Senior Engineer, Cadence Design Systems, Bangalore

Dr. Suresh Babu, Former Principal, MVJ College of Engineering, Bangalore welcoming the chief guest Dr. R Selvakumar, with a bouquet

Dr. Dr. R Selvakumar started the session by describing the important material properties of GaN and then said that GaN HEMTs are playing a transformative role in the development of technologies for 6G wireless communication systems and electric vehicles (EVs) due to their superior material properties.

Next, the speaker explained why GaN HEMTs are important for 6G and e-vehicles. We know that 6G networks are expected to operate at extremely high frequencies (e.g., sub-THz, 100 GHz–1 THz) to deliver ultra-fast data rates, low latency, and massive device connectivity. GaN HEMTs offer: (1) High Electron Mobility: Supports operation at high frequencies, (2) High Breakdown Voltage: Enables high power density operation, (3) Low Noise Figures: Critical for receiver front-end amplifiers, and (4) Thermal Stability: Sustains reliable operation under high power and heat loads.

Applications in 6G:

Power Amplifiers (PAs): GaN HEMTs are key components in high-efficiency power amplifiers for 6G base stations.
Low-Noise Amplifiers (LNAs): Crucial for reducing signal loss in high-frequency communications.

After completing the applications of HEMTs in 6-G, Dr. Selvakumar moved on to the topic of e-vehicles asked the audience that Why GaN HEMTs for EVs?

In EVs, power conversion efficiency, lightweight design, and thermal performance are crucial. GaN HEMTs offer:

Higher Efficiency: Reduce power losses in DC-DC converters and inverters.
Higher Switching Frequencies: Enable smaller and lighter passive components.
Compact Design: Allows miniaturization of power electronics systems.
Improved Thermal Management: Lower heat generation reduces cooling requirements.

Applications in EVs:
On-Board Chargers (OBCs): Faster and more efficient battery charging systems.
DC-DC Converters: Efficient power management between the battery and auxiliary systems.

The resource person, Dr.R Selvakumar delivering a talk on "GaN HEMTs for 6G & e-vehicles"

Day 07 (09-12-24) - Session 16 - "Sustainable GaN semiconductor technology beyond Silicon" | Dr. R Selvakumar, Senior Engineer, Cadence Design Systems, Bangalore

The speaker began the session by observing that GaN is widely regarded as a suitable candidate for high-performance applications beyond traditional silicon.

GaN devcis have higher electron mobility and lower on-resistance than Si devices. This reduces power loss during switching. More efficient power conversion reduces energy waste in in applications such as electric vehicles (EVs).

The wide bandgap allows GaN devices to operate at higher voltages, and temperatures without performance degradation.

The applications that drives GaN adoption are (1) Electric vehicles - Onboard chargers, Dc-DC converters (2) 6G communications - power amplifiers and high-frequency transistors

He concluded the session with key take-home messages, highlighting the challenges in sustainable GaN adoption and future directions for sustainable GaN technology.

Dr. Remashan Kariyadan, Professor, MVJ College of Engineering, honoring the chief guest, Dr. R Selvakumar with a memento

End of session-16 on day 7 with the resource person, Dr R Selvakumar

Day 08 (10-12-24) - Industrial Visit – Quest Global, Bangalore)

The FDP participants visited Quest Global's Semiconductor Division in Bangalore and interacted with its staff members. Its clients include AMD, Intel, Samsung, Qualcomm, and NVIDIA. The company has several teams working on the entire IC design process up to tape-out.

In an IC design by the Quest Global team, the average number of iterations between the RTL team and the Physical Design team is five.

According to the Quest team, one of the challenges they face is routing issues. Additionally, if a fabricated IC is not functioning correctly, the responsibility lies entirely with the design team and not the FAB team.

Currently, the quest global team work on AI chips and data centre chips.

Industrial visit to Quest Global (Semiconductor Division), Bangalore.

Industrial visit to Quest Global (Semiconductor Division), Bangalore.

Day 09 (11-12-24) - Industrial Visit – Intel Technology (India), Bangalore

The participants of the FDP visited Intel Technology in Bangalore, where they had the opportunity to interact with the company's staff. Currently, Intel's production line uses 3nm technology, which the company refers to as the I3 node. Additionally, Intel plans to launch chips based on the 2nm technology node next year.

At the Bangalore facility, all work is focused on digital design, while analog design tasks are handled at Intel's facilities in the USA.

From a technological perspective, Intel is developing a technology that will enable metal lines to be run on both the front and back sides of a wafer.

Industrial Visit – Intel Technology (India)

Industrial Visit – Intel Technology (India)

Day 10 (12-12-24) - Industrial Visit – Samsung Semiconductor India Research (SSIR), Bangalore

Samsung Semiconductor's Bangalore facility focuses on multiple fields, including memory solutions, design solutions for mobile and automotive electronics Samsung is a world leader in Memory technologies.

The design teams at the Bangalore facility focus on both analog and digital design.

Samsung Semiconductor India Research (SSIR) plans to develop analog circuits for next-generation memory products. The team aims to create innovative design solutions to enhance the performance of analog circuits, focusing on improvements in accuracy, power efficiency, and area optimization. Additionally, SSIR seeks to identify new architectures that can further boost the performance of analog circuits.

Samsung has begun chip production using 3nm process technology based on GAA-FET (Gate-All-Around Field-Effect Transistor) architecture. The company refers to this 3nm technology as NS3.

Industrial Visit – Samsung Semiconductor India Research (SSIR), Bangalore

Industrial Visit – Samsung Semiconductor India Research (SSIR), Bangalore

Day 11 (13-12-24) - Industrial Visit – Analog Devices, Bangalore

The participants of the FDP visited Analog Devices in Bangalore, where they had the opportunity to interact with the company's staff.

Analog Devices Inc. (Analog Devices) designs, manufactures, and markets analog, mixed-signal, and digital signal processing integrated circuits (ICs). The company operates fabrication facilities (FABs) outside of India, which are not accessible to external clients.

Analog Devices serves a wide range of industries, including instrumentation, aerospace and defense, building technology, consumer electronics, communications, healthcare, energy, security and surveillance, and automotive. The company focuses on developing next-generation products across these sectors.

In India, Analog Devices operates three offices in Bangalore, with a strong focus on the core digital VLSI domain. The company is involved in the full spectrum of IC design, from RTL development to GDS (tape-out) level. For IC design, Analog Devices utilizes software tools from Cadence and Synopsys, as well as proprietary in-house software tools.

It is noteworthy that Analog Devices has already started developing products that are poised to be a part of future 7G communication systems.

Industrial Visit – Analog Devices, Bangalore

Industrial Visit – Analog Devices, Bangalore

Day 12: Last day of the FDP workshop (14-12-2024)

Participants presented their reports in the morning, followed by a discussion on the reflection journals in the afternoon.

Participants working on the preparation of article summary and reflection journal

Participants with the coordinator, Dr. Remashan Kariyadan, on the concluding day of the workshop

Some of the external participants with the coordinator, Dr. Remashan Kariyadan, on the concluding day of the workshop

Conclusion:

In conclusion, the 12-day Advanced Faculty Development Programme (FDP), sponsored by ATAL Academy, provided a valuable platform for participants to enhance their research capabilities in the field of Gallium Nitride (GaN) semiconductors. The active engagement of the participants demonstrated their keen interest in staying abreast of the latest advancements in GaN technology, as well as the potential applications of GaN-based devices in next-generation technologies such as 6G communications and electric vehicles.

Outcome of the FDP:

A total of **40** participants, including faculty members from the host institution, faculty from other colleges, and professionals from the industry, actively participated in the ATAL Advanced FDP. The programme provided a valuable learning experience for all attendees, offering them the opportunity to engage with resource persons and discuss their research initiatives. Additionally, the industry visits proved to be highly beneficial, providing insights into the latest developments in integrated circuit (IC) design and fabrication.