Research Projects in the SMART LEES IRG
(September 1, 2015)

1. **Epitaxial Growth of GaAsP/InGaP on Si**
   The objective of the research will be to create state-of-the-art GaAsP/InGaP materials on silicon and engineered substrates. The GaAsP/InGaP/Si material will be deposited using advanced MOCVD equipment in the SMART laboratories. The GaAsP/InGaP/Si materials created will be used for novel devices and integrated circuits.

   MIT Principal Investigator(s):
   Jurgen MICHEL (Materials Science and Engineering)

   Singapore Co-Investigator(s):
   Soon Fatt YOON (NTU, Electrical and Electronic Engineering)

2. **Epitaxial Growth of GaN/Si**
   The objective of the research will be to create state-of-the-art GaN materials on silicon and engineered substrates. The GaN/Si material will be deposited using advanced MOCVD equipment in the SMART laboratories. The GaN/Si materials created will be used for novel devices and integrated circuits.

   MIT Principal Investigator(s):
   Eugene FITZGERALD (Materials Science and Engineering)

   Singapore Co-Investigator(s):
   Soo Jin CHUA (NUS, Electrical and Computer Engineering)

3. **Epitaxial Growth of InGaAs on Si**
   The objective of the research will be to create state-of-the-art InGaAs materials on silicon and engineered substrates. The InGaAs/Si material will be deposited using advanced MOCVD equipment in the SMART laboratories. The InGaAs/Si materials created will be used for novel devices and integrated circuits.

   MIT Principal Investigator(s):
   Eugene FITZGERALD (Materials Science and Engineering)

   Singapore Co-Investigator(s):
   Soon Fatt YOON (NTU, Electrical and Electronic Engineering)

4. **Compact Modelling for Novel III-V Devices**
   Create and interface compact models of new III-V devices into Si CMOS platform. With an innovative silicon CMOS platform which can incorporate III-V HEMTs and LEDs from different materials systems, it will be necessary to explore compact modelling for such devices so that design tools can be used to explore new circuit design.

   MIT Principal Investigator(s):
   Dimitri ANTONIADIS (Electrical Engineering and Computer Science)

   Singapore Co-Investigator(s):
   Xing ZHOU (NTU, Electrical and Electronic Engineering)

5. Engineered Substrates for III-V/Si Integration

Create novel combinations of materials with silicon for use in monolithic processes. The research will involve using state-of-the-art epitaxy and wafer bonding tools in the SMART laboratories. Some of the engineered substrates will be used collaboratively with the SMART team in order to fabricate III-V/Si CMOS integrated circuits

MIT Principal Investigator(s):
Eugene FITZGERALD (Materials Science and Engineering)

Singapore Co-Investigator(s):
Chuan Seng TAN (NTU, Electrical and Electronic Engineering)
Soon Fatt YOON (NTU, Electrical and Electronic Engineering)

6. New CMOS-Compatible Technologies for RF GaN Transistors

Development of CMOS-compatible technologies for RF GaN transistors on a Si wafer. Fabrication of state-of-the-art RF devices and characterization of their high frequency and noise performance. Close collaboration with modelling and circuit designers to tune the devices to the circuits and systems needs.

MIT Principal Investigator(s):
Tomas PALACIOS (Electrical Engineering and Computer Science)

Singapore Co-Investigator(s):
Geok Ing NG (NTU, Electrical and Computer Engineering)

7. **GaN HEMT Devices on Silicon**

Fabrication of state-of-the-art GaN high electron mobility devices on silicon. The main objective will be to push the state-of-the-art in GaN HEMTs on silicon substrates. In addition, GaN HEMTs at 0.18micron will be developed to be integrated with 0.18micron Si CMOS.

MIT Principal Investigator(s):
Tomas PALACIOS (Electrical Engineering and Computer Science)

Singapore Co-Investigator(s):
Yee Chia YEO (NUS, Electrical and Computer Engineering)

8. GaN/Si LEDs

GaN LED design and fabrication on Si. The LEDs designed in this project will be integrated with Si CMOS in a real circuit platform for a range of applications. The objective will be to design the LED for maximum performance for the given application, investigate reliability, and explore the effect of material quality on device performance.

MIT Principal Investigator(s):
Tomas PALACIOS (Electrical Engineering and Computer Science)

Singapore Co-Investigator(s):
Soo Jin CHUA (NUS, Electrical and Computer Engineering)

9. **GaAsP and InGaP Red and Yellow Green LEDs on Si**
   Visible LED design and fabrication on a Si platform. The devices will be integrated with Si CMOS in a real circuit platform for a range of applications. The objective will be to design the LED for maximum performance for the given application, investigate reliability, and explore the effect of material quality on device performance.

   MIT Principal Investigator(s):
   Jurgen MICHEL (Materials Science and Engineering)

   Singapore Co-Investigator(s):
   Soon Fatt YOON (NTU, Electrical and Electronic Engineering)

10. **InGaAs HEMT Devices on Silicon**
    Fabrication of state-of-the-art InGaAs high electron mobility devices on silicon. The main objective will be to push the state-of-the-art in InGaAs HEMTs on silicon substrates. In addition, InGaAs HEMTs at 0.18micron will be developed to be integrated with 0.18micron Si CMOS.

    MIT Principal Investigator(s):
    Dimitri ANTONIADIS (Electrical Engineering and Computer Science)

    Singapore Co-Investigator(s):
    Yee Chia YEO (NUS, Electrical and Computer Engineering)

11. **Photonic Circuit Design**
    Design of optoelectronic circuits formed monolithically in Si and Si CMOS. For the first integrated circuits of interest, linear and areal arrays of visible-wavelength LEDs and silicon photodetectors will be examined. The impact of photonic integration on system architecture will be explored.

    MIT Principal Investigator(s):
    Li-Shiuan PEH (Electrical Engineering and Computer Science)

    Singapore Co-Investigator(s):
    Wei ZHANG (NTU, Computer Engineering)

12. **Integrated Solar**
    Future low-energy systems can be charged with integrated high efficiency solar cells. High efficiency multi-junction solar cells on silicon will be explored for integration with microelectronics systems.

    MIT Principal Investigator(s):
    Eugene FITZGERALD (Materials Science and Engineering)
    Tonio BUONASSISI (Mechanical Engineering)

    Singapore Co-Investigator(s):
    Soon Fatt YOON (NTU, Electrical and Electronic Engineering)
    Armin ABERLE (NUS, Electrical and Computer Engineering)

13. Integrated Thermal Management

The success of the overall SMART team will create new challenges in integrated circuit thermal management. The goal of this project is to explore microfabricated and integrated structures for thermal management of highly integrated systems. The integrated circuits produced in SMART research will be a focus of the researched thermal management systems.

MIT Principal Investigator(s):
Evelyn WANG (Mechanical Engineering)

Singapore Co-Investigator(s):
Chuan Seng TAN (NTU, Electrical and Electronic Engineering)

14. Integrated Microbatteries

Develop new materials, designs, and prototypes for thin film microbatteries for energy storage in autonomous systems for energy management in low power circuits.

MIT Principal Investigator(s):
Yang SHAO-HORN (Materials Science and Engineering and Mechanical Engineering)
Carl V. THOMPSON (Materials Science and Engineering)

Singapore Co-Investigator(s):
Wee Kiong CHOI (NUS, Electrical and Computer Engineering)

15. Integrated Supercapacitors

Develop new materials, designs, and prototypes for silicon-based supercapacitors to be used with microbatteries for communication in autonomous systems and for energy management in low power circuits.

MIT Principal Investigator(s):
Carl V. THOMPSON (Materials Science and Engineering)
Yang SHAO-HORN (Materials Science and Engineering and Mechanical Engineering)

Singapore Co-Investigator(s):
Wee Kiong CHOI (NUS, Electrical and Computer Engineering)

16. Electronic Circuit Design

Explore the design of (i) a 4G LTE RF power amplifier and (ii) a DC-DC converter, both with power-efficiency higher than their state-of-the-art counterparts. The increased power-efficiency will be obtained by first exploiting the advantages offered by GaN-on-CMOS over CMOS-only and GaN-only, and second by exploring the possibility of novel RF PA and DC-DC converter architectures.

MIT Principal Investigator(s):
Eugene FITZGERALD (Materials Science and Engineering)

Singapore Co-Investigator(s):
Joseph CHANG (NTU, Electrical and Electronic Engineering)

17. Electronic Circuit Design, Communication

Design for novel power electronic, RF, and analog mixed signal using novel monolithic III-V/Si CMOS platform. Researchers will investigate innovation on a platform capable of mixing silicon CMOS and III-V HEMTs. Early targets for exploration are communication receiver circuits and power amplifiers.

MIT Principal Investigator(s):
Li-Shiuan PEH (Electrical Engineering and Computer Science)

Singapore Co-Investigator(s):
Chirn Chye BOON (NTU, Electrical and Electronic Engineering)

18. **Reliability of III-V Devices on Silicon**

The reliability of the unique devices produced through this program will be characterized to fully validate the technology. This will also provide new insight into the general mechanisms that control the reliability of compound semiconductor devices

MIT Principal Investigator(s):
Carl V. THOMPSON (Materials Science and Engineering)

Singapore Co-Investigator(s):
Chee Lip GAN (NTU, Materials Science and Engineering)

19. **Capacitive Desalination Battery**

A new type of desalination battery based on electric double layer capacitor technology has drawn great attentions due to its feasible practical applications. Since the battery efficiency is closely related to the properties of electrode' material, i.e. micro-structure, inner conductivity and surface area, the goal of this project is to design novel nanostructured material by facile chemical/physical approach as well as new device for high efficiency capacitive desalination battery.

MIT Principal Investigator(s):
Yang SHAO-HORN (Materials Science and Engineering and Mechanical Engineering)

Singapore Co-Investigator(s):
Hui Ying YANG (SUTD, Engineering Product Development)