Research Projects in the SMART LEES IRG
(August 3, 2018)

1. **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)

2. **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)

3. **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):**
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4. Stained-Ge Photo-detector Beyond 1.55 µm

Group IV photonics has recently drawn significant research attention, for example, in application of CMOS-compatible photonic-integrated circuits for high speed and low power data transmission. Active optoelectronic devices such as photodetectors are important building blocks to realize such platform. In state-of-art technology, Germanium (Ge)-based photodetectors have been widely investigated in fiber optical communication (1.3 and 1.55 µm) applications. However, studies are still lacking on CMOS-compatible photodetectors operating in Short-wave Infrared (SWIR) regime (i.e. 2.0 to 2.5 µm). This is due to technical challenges that silicon (Si) and Ge are optically transparent at these wavelengths and high quality GeSn material growth is still difficult to achieve. On the other hand, optical communication in SWIR regime could not only extend the current fiber optical communication bandwidth, but also explore diversified sensing and imaging applications. Given these motivations, this PhD work aims to extend the operating wavelength of Ge photodetector towards 2 µm using strain engineering technique. For example, tensile strain provided by SiN deposition, which is capable of reducing the bandgap of Ge material, will be investigated to achieve the targeted 2µm detection. Currently, P-i-N normal incidence unstrained Ge photodetector has been successfully demonstrated on Ge-on-Insulator (GOI) substrate, with dark current density of 4x10^-1 A/cm² and responsivity of 0.4 A/W. Future work will be focused on optimizing the Ge photodetector performance and integrating SiN process for successful 2µm photodetector fabrication.

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

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

5. 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 novel materials and microfabricated 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)
6. Integrated Microbatteries
Develop new materials, designs, and prototypes for thin film microbatteries for energy storage in autonomous systems and for energy management in low power circuits.

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

**Singapore Co-Investigator(s):**
Li LU (NUS, Mechanical Engineering)

7. The next generation of nanoscale light emitters
The goal of this project is to develop the next generation on nanoscale light emitting devices for high density displays and general lighting. Integration of III-V materials — specifically, (Al,Ga,In)N — on silicon platform will be investigated by combining a set of complementary experimental techniques. In addition to materials development using metalorganic chemical vapor deposition, strong emphasis will be given on direct correlation of structural and optical properties of these materials using state-of-the-art electron microscopy facilities at NUS. Finally, device fabrication based on (Al,Ga,In)N heterostructures on Si will be used as a testbed toward systems integration.

**MIT Principal Investigator(s):**
Silvija GRADECAK (Materials Science and Engineering)

**Singapore Co-Investigator(s):**
Stephen PENNYCOOK (NUS, Materials Science and Engineering)

8. Advanced GaN transistors and integration with Si-CMOS
GaN transistors are emerging as one of most popular technologies for next generation RF and power applications. This project is aimed to develop advanced structures and fabrication technologies for high-performance GaN transistors, and integrate GaN with Si-MOS to realize more functional, small size and cost effective hybrid circuits.

**MIT Principal Investigator(s):**
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