Summary Report of the Study Session on

Phosphor-Free White LEDs for Solid State Lighting

The Study Session on *Phosphor-Free White LEDs for Solid State Lighting* was held at McGill University on Jan. 11, 2013. There were over 50 participants, including 16 professors from 6 Canadian universities and over 20 people from 18 companies in Canada. The participants also included two keynote speakers: Prof. Fred Schubert at Rensselaer Polytechnic Institute, a world leader in solid state lighting, and Dr. George Wang at Sandia National Labs, one of the pioneers of nanowire LEDs. The detailed program description is included in Appendix A. The list of participants is shown in Appendix B.

Through in-depth presentations, extensive discussions, and invigorating debates, we have identified the following important facts and trends for solid state lighting.

1. Solid state lighting promises tremendous energy benefits (they can be 20× more efficient than incandescent and 5× more efficient than fluorescent lighting), environmental and economic benefits (significant reduction of CO_2, SO_2, and Hg emissions), and financial benefits (electrical energy cost reduction and savings resulting from less pollution and global warming).

2. With an annual growth rate of more than 10%, the LED lighting market will well exceed $15-billion in 2017, which does not include the cost associated with light fixtures and electronic drivers, representing a tremendous opportunity for the Canadian manufacturing industry.

3. The efficiency of LEDs is expected to reach ~ 150 lumens/watt by 2015 and ~ 200 lumens/watt by 2020. However, the market penetration of solid state lamps is severely limited by the lamp cost, stability, and light quality, which are related, by and large, to the use of phosphor coating in the current technology. *Therefore, the development of phosphor-free white LEDs is extremely urgent and crucial for the continuous market penetration of solid state lamps.* As stated by Mr. Patrick Durand, Worldwide Technical Director of Future Lighting Solutions, ***"Those who can develop and commercialize phosphor-free solid state lamps will rule the lighting market."***

4. Nanowire LEDs have emerged as the most promising approach for phosphor-free solid state lighting. Many countries have started investing heavily in this field. An example is the $18-million *Solid State Lighting Science Energy Frontier Research Center* at Sandia National Labs in USA, where Dr. George Wang is a senior Leadership Council Member.

5. Controllable light sources will enable a wealth of new functionalities, which include circadian lights, visible light communications, and light sources that can enhance plant growth and tissue/cell visualization, to name just a few.

The workshop has also made the following observations.

1. There is a clear need of a national network for the development of phosphor-free solid state lamps, given the complexity of this manufacturing process.

2. With the objective to demonstrate, for the first time, phosphor-free solid state lamps with more than 200 lumens/watt, this NSERC network grant targets at the missing link in the Canadian lighting industry, i.e. the development of core LED devices, which will bridge the critical gap in the manufacturing chain of solid state lamps in Canada, create a healthy ecosystem required for a vibrant lighting industry, and produce tremendous impact on a broad array of sectors including communications, energy, electronics, and forestry.

3. This team, with 16 professors from 6 Canadian Universities, consists of the best minds in this field in Canada. Their innovative work, evidenced by more than 40 patents related to LEDs, is at the leading edge of this technology development.

4. The growth of solid state lighting industry will significantly increase the demand for raw materials, services, construction, and energy from a broad range of supplying industries, thereby spurring the creation of new jobs in many sectors. This is evident by the strong participations from some related business sectors, including forestry (FPInnovations), microelectronics (CMC Microsystems and C2MI), optics (Silonex), and automotive (TE Connectivity).

The participation of industrial partners is critical to the success of the network. During the workshop we received several critical suggestions/comments from the industrial partners regarding this network proposal and revised the research projects accordingly (Appendix C). The following new research projects will be included in the network proposal, based on the strong engagement from a number of industrial partners.

1. *LEDs on Flexible Substrates*, which will address the growing demand for flat panel displays and low cost lighting applications.

2. *High Quality Ga(In)N Templates on Si and Amorphous Glass*, which will provide a powerful platform for the development of full-color LEDs utilizing both the emerging nanowire and conventional quantum well technologies. In addition, it will provide the low cost, high quality substrates needed by the massive GaN-based electronics industry.

3. *Novel Transparent Conductive Electrodes*, which will address the increasing cost of conventional ITO electrode and is critical for the ultimate commercialization of nanowire LEDs.

Additionally, our industrial partners expressed a range of objectives they hope to achieve through their participation in the network. Overall we felt there were several general categories: looking to acquire knowledge in an emerging industry, accessing newly developed technologies, identifying technology trends, training of HQP, and finding solutions to their technical issues. Also of note, several industrial partners expressed the desire to work with each other as well as

directly with the university research team. In order for our industrial partners to fully benefit from their participation, we will establish a flexible network structure to ensure they can achieve their objectives.

In the upcoming days and weeks, we will continue to have in-depth discussions with the workshop participants to further define and redefine the research projects and scope of this network proposal.

Finally, as stated in the welcome remarks by Dean Andew Kirk, McGill University has received significant investments in support of solid state lighting and related fields.

1. McGill is equipped with state-of-the-art technology computer aided design (TCAD), materials growth, fabrication, and characterization facilities related to the development of phosphor-free white LEDs. More recently, McGill has received $11.2-million CFI investment (led by Prof. Peter Grutter), which will lead to substantial upgrades in the LED design, growth, fabrication and characterization infrastructures.

2. With $15-million donation from the family foundation of Lorne Trottier, McGill University has recently established the *Institute for Sustainability in Engineering and Design*, which, through concerted and collaborative efforts, will help harness the full potential of the disruptive lighting technology we develop throughout this program.