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Date: Mon, 2 Jul 2012 15:13:25 -0400
Subject: RE: Concept Paper on WBG Pilot Institute/MDF

Dear Mike,

I have been attending the NNMI Workshops, and also plan to attend the July 9, 2012 Workshop in Cleveland, OH.

For the past 30 years or so, I have been working in the area of Wide Bandgap Semiconductors (WBG), especially for energy conversion and communication applications - collaboratively with industry, academia and government labs.

Since I started attending the first such Workshop organized by DOE AMP office in Chicago in April 2012, I have been communicating with many of my collaborators to see if they would be interested in being part of a "WBG Manufacturing Initiative." The initial response has been overwhelmingly positive.

So, I decided to put together a 2-page Concept Paper on this topic and have attached to this email. I hope you read this report and provide some time for me to meet with you and your colleagues from NIST and other agencies to discuss this topic in more detail at the July 9 Workshop in Cleveland. Some of my collaborators may also be attending this Workshop.

Thank you in advance for your kind consideration and please do not hesitate to contact me if you need any clarifications. I can be reached on my cell phone at (630) 788-5241.

Sincerely,

Krishna Shenai, PhD
Professor

Wide Bandgap Semiconductor Manufacturing Initiative

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1. Vision and Rationale:

Wide bandgap semiconductors, especially Silicon Carbide (SiC) and Gallium Nitride (GaN) offer tremendous opportunities for transformative changes in the generation and utilization of electrical energy, communication and sensing, and defense and space electronics. Some key commercial products that are poised to significantly benefit from these semiconductors include: solid-state energy converters, power amplifiers, light-emitting diodes (LEDs), solar cells, lasers, and environmental sensors. The global annual market size for these products is collectively in the range of one hundred billion US dollars. Compared to the semiconductor silicon, SiC and GaN offer significantly higher electrical and thermal conductivities, increased avalanche breakdown field strength, and improved ruggedness under harsh environmental operating conditions. These basic material properties translate into more compact and lightweight OEM systems, significant energy savings, much improved signal sensing and transmission characteristics, and longer operating life in the field.

In the US, there has been very significant investment in the past two decades or so to advance material, device and systems technologies employing SiC and GaN semiconductors. However, commercialization has been seriously impeded because of a lack of "systems-driven" and "reliability-focused" R&D and manufacturing efforts. For example, large-scale deployment of SiC- and GaN-based material technologies in energy- and communication-electronics has not occurred because of low manufacturing yield and poor field-reliability; this problem is compounded due to a very high density of native crystal defects inherently present in bulk and epitaxial materials. Many European countries, Japan, and now China and India have invested hundreds of millions of US dollars on R&D and manufacturing activities to advanced SiC and GaN material growth-technologies. Unfortunately, the current level of investment in the US to advance growth of SiC and GaN semiconductors is almost negligible. The impact is already felt in strategic defense, space and commercial sectors in that the US is significantly behind in manufacturing of SiC- and GaN-based products. The problem is further alleviated because many reputed US universities and community colleges are unable to produce trained human resource to feed into the manufacturing sector, primarily because of lack of adequate support and encouragement from industry and government. This situation is only getting worse unless proper measures are immediately put into place.

A nationally centric effort geared towards improving the manufacturing competitiveness of US industries in this strategic area is imminently needed. With a modest investment of about $100 million for up to five years, a shared R&D effort focused on key areas of manufacturing and human resource development, a self-sustaining industry-university-government collaborative infrastructure can be established in order to improve US competitiveness, create small businesses, generate high-technology jobs, and rapidly penetrate global market.

2. Three Key Projects:

In order to make maximum impact on US economy, we suggest the following three initial projects to be conducted that are common to most, if not all, product application sectors of SiC and GaN semiconductors:

1. *Defect-Free Bulk and Epitaxial Material Development:* It is clear that conventional material growth processes employed in industry today have very limited prospect in terms of further reducing crystal

defects while improving growth rates. Radically different material growth technologies need to be developed that are commercially viable. Key industry stakeholders in this project are likely to include: companies that develop growth reactors, substrate and epitaxial wafers, and software simulation tools used to optimize the growth technology and reactor designs.

2. *Develop New Manufacturing Yield and Product Reliability Assessment Methodologies:* An important factor that has hindered rapid commercialization of SiC and GaN device technologies, especially in energy conversion and communication electronics, is lack of adequate testing and modeling techniques that can be used to assess manufacturing yield and field-reliability of end-products. The problem is complex since both electrical and thermal effects need to be considered in actual field operating conditions. New accelerated stress-testing, reliability modeling, and yield estimation approaches that are realistic and relating to cost and "end-of-life" performance need to be developed. Key industry stakeholders in this project are likely to include: companies that develop power devices and packaged power modules, power converters and power amplifiers, software simulation tools used to optimize device and circuit designs, and equipment used for test and measurement.

3. *Develop Critical Chip Manufacturing Processes:* For most applications, a Metal-Oxide-Semiconductor (MOS) device is needed; also for power electronics switching, minority career lifetime control is crucial, especially for bipolar-mode power switching devices. Stable MOS interfaces with a low interface state density is currently a critical challenge for industry; so are accurate measurement and control of minority career lifetime. Another critical challenge is the development of thermally-stable, low-resistance, multi-level metallization and high-voltage passivation technology. Key industry stakeholders in this project are likely to include: companies that develop power devices and packaged power modules, software simulation tools used to optimize device and manufacturing processes, and equipment used for manufacturing processes and test/measurement.

3. Key Objectives and Governing Structure:

The main objectives of this initiative are: (1) increase US competitiveness in the manufacturing of wide bandgap semiconductor technologies, (2) generate trained human resource and supporting infrastructure, and (3) create high-technology jobs to rapidly improve US economy. The industry will cost-match 50:50 during the first five years when this new initiative is receiving federal funding; and, beyond five years, the organization will be self-sustaining, primarily based on funding received from industry, revenue generated from licensing of new intellectual property (IP) generated, and other sponsored research projects. The initiative will promote collaborative environment with participation from industry, academia, and national labs. It will be managed by a governing board with members selected from key stakeholders, and will be adequately staffed with highly qualified and skilled personnel to perform R&D, manufacturing transition and administration.

4. Current Status:

There is already significant interest from several potential participants from industry, academia and national labs. We should be able to put together a credible proposal within a very short time period.