David Isaacs, Semiconductor Industry Association

Subject: Comments of SIA on the NNI Strategic Plan
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To: "2014NNIStrategy@nnco.nano.gov" <2014NNIStrategy@nnco.nano.gov>

On behalf of the Semiconductor Industry Association (SIA), please find attached a brief summary of our comments on the NNI Strategic Plan (first attachment), along with more detailed comments (second attachment). We look forward to further engagement in the NNI in the future.

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Attachments:
SIA NNI summary dec 2013.docx.pdf 349 KB
SIA NNI comments dec 2013.pdf 477 KB

David Isaacs, Semiconductor Industry Association

SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

Summary Comments of the Semiconductor Industry Association (SIA)
On the
National Nanotechnology Initiative (NNI) Strategic Plan

The U.S. semiconductor industry relies on the pipeline of new scientific ideas, breakthroughs, and highly-trained students that can only come from the broad research enabled by strong and consistent Federal funding of the U.S. university system. The National Nanotechnology Initiative (NNI) has played a key role in accelerating progress at the leading edge of nanoscale science and engineering — an area that is critical to the future of the semiconductor industry and the future drivers of our economy and job growth over the long-term. As you consider the NNI and its future, please consider the following:

1. **Nanoelectronics is a priority** for the economy, for high paying jobs, and for the nation's ability to innovate and compete in the future. As the Administration and Congress works to reduce the Federal deficit, it must give priority to those expenditures that create the long term economic growth and jobs that will expand our tax base and raise our standard of living.
2. Strong university research correlates geographically with leading edge technology development and flourishing technology businesses. **If the United States is to lead in nanoelectronics, it needs a robust university research effort in nanoelectronics**. Government and private sector funded university research should be done in a coordinated or, better yet, collaborative manner.
3. The electronics industry is facing a challenge similar to the 1940's, when vacuum tubes were replaced by semiconductor chips. **The nation that is first to discover and develop the key nanotechnologies—i.e., the next logic "switch"—will lead the nanoelectronics era,** much like the United States has led the microelectronics era for the past half century. This fact is recognized by countries around the world and U.S. leadership is far from guaranteed.
4. **NRI is an industry-driven consortium that funds a coordinated program of university research in partnership with Federal and State government agencies**. Thanks in large part to NRI, the United States is the current leader in nanoelectronics at this early stage. But the challenges are great and the global competition is growing.
5. **Funding university scientific research educates our technology workforce**. A pipeline of science and engineering graduates is critical to growing and keeping the very businesses that will help to rebuild the economy. Funding for the NNI and other scientific research ensures the pipeline is adequately filled. NRI-funded students also have meaningful interactions with industry mentors, which enhance their education, expose them to career opportunities, and allow them to contribute productively once they graduate.

SIA suggests the following recommendations for strengthening the NNI and ensuring the United States' leadership in nanoelectronics:

1. The Federal government should continue its support for the National Nanotechnology Initiative, especially in the "Signature Initiative" on long-term nanoelectronics research (pp. 46-47).
2. Congress should reauthorize the NNI and the participating agencies, to make clear its desire to see nanotechnology research remain a priority by the agencies that fund science and engineering research today.

3. The NNI agencies that are part of the nanoelectronics Signature Initiative should leverage each other's investments and those of NRI, to get the most out of every dollar spent.
4. The participating agencies should develop interdisciplinary nanotechnology initiatives that are supported by multiple NNI agencies and that support significant national priorities.
5. In choosing research priorities, NNI agencies and the interagency coordinating bodies should give strong consideration to the potential long-term economic impact of the research area, with key positive indicators being:

    a. Support of a broad research agenda that will create enabling breakthroughs for a large market segment, rather than choosing to focus on just one or two specific technologies
    b. Early engagement of industry to facilitate rapid transfer of knowledge and ideas from university scientific research into the hands of those who can use them in commercial applications.

SIA also supports the goal of the responsible development of nanotechnology (Goal 4) and the objectives under that goal. Because of the potential importance of nanotechnology in future advances in semiconductor manufacturing that are essential for continued U.S. leadership in this critical industry, it is essential that concerns over the environmental, health, and safety (EHS) impacts of nanotechnology do not impede new advancements in this area. Accordingly, government and industry must collaborate to further nano-EHS research and ensure that future innovations are developed in a responsible manner, and SIA looks forward to working with EPA, NIOSH, and other agencies that are part of the NNI to achieve that goal.

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SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

Comments of the Semiconductor Industry Association (SIA)
On the
National Nanotechnology Initiative (NNI) Strategic Plan

The Semiconductor Industry Association (SIA) supports the strategic plan for the National Nanotechnology Initiative (NNI), particularly the "Signature Initiativefor Nanoelectronics for 2020 and Beyond." (pp 46-47)). Semiconductors are the fundamental enabling technology of modern electronics, and the nation that is first to discover and develop the key underlying technologies will lead the nanoelectronics era in the future, and gain the benefits for the economy, the high paying jobs, and the ability to innovate and compete in the future. U.S. leadership in this area is not guaranteed. Future nanoelectronics-enabled products will be desgined and manufactured in the U.S. if we invest and choose to be the region that first discovers and markets these new technologies. We must make strategic choices and acknowledge that nanelectronics infrastructure and scientific research provide the nation the best return on its tactical and strategic economic investments.

The U.S. technology-based economy in general, and the semiconductor industry in particular, relies heavily on the pipeline of new scientific ideas, breakthroughs, and highly-trained students that can only come from the broad research enabled by consistent Federal funding of the U.S. university system. Within that spectrum of research, the National Nanotechnology Initiative (NNI) has played a key role in accelerating progress at the leading edge of nanoscale science and engineering—an area that is critical to the future of the semiconductor industry. As you consider the NNI and its future, please consider the following:

1. **Nanoelectronics is a priority** for the economy, for high paying jobs, and for the nation's ability to innovate and compete in the future. As the Administration and Congress works to reduce the Federal deficit, it must give priority to those expenditures that create the long term economic growth and jobs that will expand our tax base and raise our standard of living.

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4. **NRI is an industry-driven consortium that funds a coordinated program of university research in partnership with Federal and State government agencies**. Thanks in large

part to NRI, the United States is the current leader in nanoelectronics at this early stage. But the challenges are great and the global competition is growing.

5. **Funding university scientific research educates our technology workforce**. A pipeline of science and engineering graduates is critical to growing and keeping the very businesses that will help to rebuild the economy. Funding for the NNI and other scientific research ensures the pipeline is adequately filled. NRI-funded students also have meaningful interactions with industry mentors, which enhance their education, expose them to career opportunities, and allow them to contribute productively once they graduate.

Recommendations for strengthening the NNI and ensuring the United States' leadership in nanoelectronics:

1. The Federal government should continue its support for the National Nanotechnology Initiative, especially in the "Signature Initiative" on long-term nanoelectronics research (the Nanotechnology Signature Initiatives (NSI) for Nanoelectronics for 2020 and Beyond (pp 46-47)).

2. Congress should reauthorize the NNI and the participating agencies, to make clear its desire to see nanotechnology research remain a priority by the agencies that fund science and engineering research today.

3. The NNI agencies that are part of the nanoelectronics Signature Initiative should leverage each other's investments and those of NRI, to get the most out of every dollar spent.

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Federal investment in Nanoelectronics research is priority for continued U.S. economic growth

Nanotechnology is the understanding and control of matter on the scale of atoms and molecules. Nanotechnology is making it possible to build machines on the scale of human cells and create materials and structures from the bottom up, building in desired properties.

Nanotechnology and research supported by the NNI is impacting many industries, but SIA would like to highlight the enormous impact the investment in nanoelectronics in particular could have on the future of the semiconductor industry and the potential scale of that impact on the U.S. economy.

Semiconductor industry of today

The remarkable growth in semiconductor jobs and revenues through the years has been made possible by continuous technological advances based on the semiconductor transistor; it is the "switch" that creates the ones and zeros in our digital world and is the fundamental building block in electronics. Transistors are in the "chips" that permeate modern life, enabling computers, smart phones, the internet, national defense applications such as night vision goggles and unmanned aircraft, video entertainment, automobile systems such as antilock brakes and traction control, medical imaging devices, factory robotics, and countless other uses. Advances over the last 60 years have led to smaller and smaller transistors, which in turn have enabled dramatic increases in performance and function, and decreases in cost.

Nanoelectronics industry of tomorrow

The semiconductor industry by any measure has been hugely successful. But today's transistor technology is approaching fundamental physical limits that will prevent further improvements if we don't find alternative technologies. You might ask, "Why do we need even more capable technology?" Imagine a future in which a child with diabetes no longer has to prick her finger to check her glucose or get insulin shots thanks to an implanted artificial pancreas; when smart tools and sensors enable a highly efficient electric grid that saves billions of dollars in wasted energy costs and avoids the need for new power plants based on non-renewable energy; or powerful systems to design and manufacture new materials for radically lighter, yet safer, cars and planes. Each of these is a grand challenge for science and engineering, but underlying them all are nanoelectronics—the devices that will make our future world smart and efficient, and without which many solutions will remain out of reach.

In fact, **we are in a race to find a replacement technology for the transistor—to address technological needs and challenges, and to do so first.** U.S. researchers made the discoveries that led to the microelectronics industry, thanks to early support for research and development by the Federal government. The United States continues to dominate the development of new technology, due in large part to continued Federal support for scientific research. But today, many other countries have made it a goal to attract and build semiconductor businesses. When faced with generous financial incentives to locate not only manufacturing but also research facilities overseas, one factor that is in favor of locating operations in the United States is access to the best university faculty and student researchers.

NRI is leading the way in collaborative research in nanoelectronics

The Nanoelectronics Research Initiative (NRI) is a consortium within the Semiconductor Research Corporation (SRC) that leverages contributions from industry, universities, and governments (local, State and Federal) to fund collaborative research at over thirty U.S. universities. SIA is pleased with the Administration's continued strong support for this "exemplar" program.

NRI is focused on the key challenge for continuing the progress in semiconductor electronics which has fueled the world economy for the past 50 years: finding the next "switch" and thereby keeping the United States at the forefront of the nanoelectronics revolution.

NRI funds multi-disciplinary research in physics, chemistry, materials science, and engineering that addresses fundamental problems standing in the way of progress toward "real world" applications. The consortium is open to any U.S.-based company and potentially useful technologies that emerge are efficiently shared with all team members. NRI not only funds the university research, it coordinates among the universities and between industry and academia, avoiding duplication and encouraging collaboration.

NRI research is at an early stage, and like most scientific research, it is unlikely to become part of a commercial product any time soon. Such long-term, high-risk research is typically funded by the Federal government. Yet NRI industry members contribute millions of dollars each year because of the importance of the research to their long-term future. They also dedicate company researchers to work alongside the university researchers, helping to accelerate progress even at the beginning stages of the research and to insure strong technology transfer paths are in place for the future.

NRI is partnering with the Federal government

In addition to having members from industry, NRI partners with Federal agencies whose missions align with NRI's. The National Institute of Standards and Technology (NIST), which has a mission to promote U.S. innovation and industrial advancements, co-funds the university research and contributes in-house resources (staff and facilities). The National Science Foundation (NSF) is the primary funding agency of physical science and engineering university research and funds a number of Nanoscale Science and Engineering Centers related to nanoelectronics. NRI provides additional support and engages Center researchers in annual reviews and web-based workshops and seminars. All of these partnerships have been enabled by the strong support and focus the NNI has brought on to nanoelectronics.

The NRI partnerships with NIST and NSF make sense. Without Federal funding for scientific research, there would be devastating consequences for the NRI mission. And **bringing together industry, university, and government scientists and engineers benefits all parties.** University researchers are more aware of the diverse, longer-term challenges faced by industry. Industry stays abreast of academic research and develops relationships with top-notch faculty. Government scientists and program managers understand future industry needs and can thereby enhance the value of their own research

missions.

In addition to jointly funding research with NRI, the Federal government has built and maintained the world's best university system through the NNI and its broader research initiatives. American research universities produce graduates with advanced degrees who lead the world in innovation—creating new products, new businesses, and even new industries. NRI's modest and targeted investments are effective—and in fact are only possible—because of the ongoing Federal support for university research broadly. **Sustained Federal support for science and engineering research is absolutely vital if government-university-industry initiatives like NRI are to succeed.**

Technology transfer is built into NRI

A benefit of NRI is the seamless transition of research results from the university researchers to NRI member companies. Because industry has "skin in the game", industry representatives are more engaged—providing feedback during the course of the research and taking results back to others in the company. In addition, as students graduate and are hired, they bring with them detailed understanding of the research. This approach has worked well. NRI is hopeful that agencies that support nanoelectronics research in addition to NIST and NSF will also elect to join.

Supporting research supports education and workforce development

In fact, NRI has two primary outputs, both of which are valuable to member companies and to the greater science and technology enterprise. One output is the research results, which researchers are allowed to make public and disseminate broadly. The other is the students who perform the research as part of their studies and who are highly sought after as employees upon graduation. Graduates are well prepared and are able to contribute to nanoelectronics research and development once hired.

NRI-funded students are not obligated to take a position with a member company, although many do. NRI graduates also take positions as university or government researchers, or in other parts of the private sector. Through its publications, presentations, and graduates, NRI is benefiting a much larger segment of the U.S. economy than just its members.

SRC and SIA applaud the NNI Signature Initiative on "Nanoelectronics for 2020 and Beyond"

NNI has taken steps to focus some of its investments in areas of potentially high impact. SIA supports the NNI Strategic Plan's "five thrust areas" in the "Nanoelectronics for 2020 and Beyond" and is encouraged be marked progress over the past few years. SIA continues to strongly support the Administration's budget requests related to the NNI nanoelectronics signature initiative.

We are pleased that the NNI agencies recognize that the field of nanoelectronics has the potential for significant economic contributions. As the leading entity in the field of

nanoelectronics and a strong supporter of university research in this area, we look forward to working with other "target agencies", in addition to NSF and NIST, to coordinate and collaborate on research that will provide the greatest value and lead to the greatest progress.

SIA supports the Responsible Development of Nanotechnology

The semiconductor industry fully supports the goal of the responsible development of nanotechnology (Goal 4) and the objectives under that goal. Our industry contributes to efforts to achieve this goal through the implementation of a comprehensive nanotechnology-related environmental, health, and safety (nano-EHS) research strategy. Our companies work in coordination with research entities, including SEMATECH, the Semiconductor Research Corporation (SRC), and the Center for Nanoscale Science and Engineering (CNSE), to conduct research and technical studies and to fund university research on nano-EHS research applicable to our industry. We are also collaborating with our colleagues internationally on nano-EHS research under the auspices of the World Semiconductor Council (WSC).

One of the key steps in the fabrication of semiconductor devices is chemical mechanical planarization (CMP), and this process can include the use of engineered nanoparticles (ENP) such as alumina, ceria, and silica.[1] The industry employs a variety of engineering controls and processes to minimize releases of these materials to the environment. In addition, because an inherent feature of the semiconductor manufacturing process is to isolate the production process from workers by employing sterile "clean room" environments, enclosed systems, and personal protective equipment (PPE), the exposure of workers to these materials is minimized.

Because of the potential importance of nanotechnology in future advances in semiconductor manufacturing that are essential for continued U.S. leadership in this critical industry, it is essential that concerns over the EHS impacts of nanotechnology do not impede new advancements in this area. Accordingly, government and industry must collaborate to further nano-EHS research and ensure that future innovations are developed in a responsible manner. SIA looks forward to working with EPA, NIOSH, and other agencies that are part of the NNI to achieve that goal

Conclusion

Our nation faces a challenge that can be compared with the transitions that occurred from vacuum tubes to the transistor and on to integrated circuits and to large scale semiconductor systems. The United States led the semiconductor industry through these

[1] It should be noted that finished semiconductor products contain features at the nanoscale, but these features are not released from the product and do not present EHS impacts. The nanoscale features are the structure and junctions of transistors on an integrated circuit that have enabled modern semiconductors to drive the advancements in technology in information technology, communications, health care, transportation, and other aspects of our economy. Nano-sized features in semiconductors are etched or otherwise formed into the layers and sections of carefully added metals, organic-metallic complexes, organics and other materials in the semiconductor that are not themselves nanoscale particles..

challenging transitions. We led because of our public and private research strengths and our formidable university research infrastructure. It required substantial investment of Federal funds to create the first semiconductor diode, initially for military use. Those investments launched the entire IT industry, which has driven the economy ever since. We led because entrepreneurs incorporated this research into products that created new industry segments. And the Federal government played a critical role all along the way.

Today, the U.S. semiconductor industry has nearly fifty percent of the approximate $300 billion worldwide market share. In a globalized economy, research must begin far in advance of the technological transitions we will encounter. Luckily, we know the broad outline of some of these challenges, and by funding research in nanoelectronics, Congress will lay the bedrock for new U.S. jobs and industries of the future, much like those that were enabled by the transistor age. We are creating something wholly new with untold potential, and this research is taking place here in this country through the NRI and other SRC programs, our public-private partnerships, and nanoelectronics focused programs at NSF, NIST, DoD and the Department of Energy.

Future nanoelectronics-enabled products will be designed and manufactured in the United States if we choose to be the region that discovers and markets these new technologies first. The latter is largely dependent upon making strategic choices today and acknowledging that nanoelectronics infrastructure and scientific research provide our nation the best return on its tactical and strategic economic investments.

In the middle of the last century, Silicon Valley grew from innovation built on Federal research. What are the names of the companies that will dot the horizon of the new "Nanoelectronics Valley?" The question is not whether this place will exist, but rather where will it be.