Center for Scalable and Integrated NanoManufacturing (SINAM)

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Overview

Center for Scalable and Integrated NAno Manufacturing (SINAM) embraces a vision for a new manufacturing paradigm that combines fundamental science and technology in nano-manufacturing, and that will transform laboratory science into industrial applications, in nano-electronics, biomedicine, and in traditional industries. We have organized an exceptional team of scientists and engineers from six institutions: UCLA, UC Berkeley, Stanford, UCSD, University of North Carolina and HP Labs to embark on this important mission. SINAM is targeting a new nano-manufacturing paradigm based on fundamental scientific research; one that will enable an industrial quantum-leap by working closely with industry; and that will forge a new education platform for multidisciplinary science and engineering through integrating research and education.

Goals and Approaches

SINAM set its goal to develop a 3D nano-manufacturing platform to achieve the 3D heterogeneous integration of sensing, computing, actuation and communication on a single chip. To address the niche applications, we believe that flexible and agile manufacturing is essential to keep the cutting edge in nanotechnology. SINAM's research strategy is to fuse the top-down and bottom-up manufacturing approaches by integrating a highly multidisciplinary team effort at system level. Driven by strong system focus, SINAM develops system engineering strategies to scale up the nano-manufacturing technologies.

Integrated Research Plan

SINAM's research program is structured through three integrated research groups. IRG 1 focuses on top-down nano-lithography aiming toward critical resolution of 1-50 nm. IRG 2 explores the novel hybrid approaches, in combining the top-down and bottom-up technologies to achieve massively parallel integration of heterogeneous nanoscale components into higher-order structures and devices. IRG 3 develops system engineering strategies to scale up the technologies developed in IRG 1&2, and in product design and development.

IRG 1: New Top-down nano-manufacturing technologies

A plasmonic imaging lithography (PIL) is taking advantage of surface plasmon waves on metals, which fulfill our mantra "*optical frequencies, but with X-ray wavelengths*": Amazingly surface plasmons at visible frequencies can have wavelengths down to 1 nm. Surface plasmon optics and lenses convert free space waves into surface waves, whose short wavelength allows unprecedented resolution of 1-10 nm in the final optical image. These surface plasmonic waves can then be used to expose photo-resist at resolution of 1-50 nm.

In addition, an ultra molding and imprinting (UMIL) technology promises the nanomanufacturing at 1nm resolution. The key to investigate UMIL is the usage of epitaxially grown superlattices to make 1-10 nm molds in 2D applications that require molecular level resolution. A multi-layered Si/SiGe superlattice can be deposited sequentially onto the substrate followed by a CMP planarization on the side wall. SiGe layers are then selectively etched back from a Si/SiGe superlattice, leaving the silicon fins as an imprinting mold. The advantage of UMIL technique is that the width and pitch of the lines are precisely defined by the epitaxial layer with thickness ranging from 0.5 to 20 nm.

IRG 2: Hybrid Top-down and Bottom-up Process (HTBP)

Concurrent to the development of top-down nanomanufacturing technology, SINAM will develop a unique technology, Hybrid Top-down and Bottom-up Process (HTBP), that combines the best aspects of top-down and bottom-up techniques for *massively parallel* integration of *heterogeneous* nano components into higher-order structures and devices. HTBP assembles by "pick-and-place" the nanoscale functional components, namely nano-LEGOs, into a defined pattern (a top-down approach); then the functional molecules attached to the nano-LEGOs can start to "glue" the adjacent nano-LEGOs by self-assembly, thus forming a stable structure (a bottom-up approach). Depending on designed functionalities, the nano-LEGOs can be in the form of nano-wire, quantum dots, DNA, protein, and other functional entities.

We are conducting material development and optimization for nano-manufacturing, and in addition developing modeling tools for accurate prediction of process and device performance. SINAM will further pursue device applications and product development based on both top-down and hybrid methods. A few examples of engineered products include: a 3D nano-photonic circuit for integrating optical communication and computing, a nano-multiplexed molecule assembler, an integrated pathogen bio-sensor, and 3D Terabit programmable molecule logic arrays.

IRG 3: System engineering and design for nano-manufacturing

SINAM research is driven by a strong system focus with the emphasis on manufacturability, scalability, and reliability. All the concepts have to withstand such system oriented scrutiny. This IRG develops strategies for the nano-manufacturing system and the design process. An innovative concurrent design and nano-CAD platform will be developed to reduce the prototyping cycle, and enhance the scalability. SINAM is investigating the key factors in both design and manufacturing for reliability, and this effort has been jointly pursued in partnership with Sandia National Laboratory's reliability group.

SINAM's strong focus on Design and Development is exemplified by IRG 1-3. This strong connection is especially important to 3D nano-manufacturing because the heterogeneous integration of nanodevices opens the door to new device architectures which are beyond current IC design paradigm. We anticipate a push-and-pull mechanism in product and process developments: the rapidly expanding nano-manufacturing process capabilities with increasing device complexities will inspire nanodevice designers to explore innovative ideas and novel artifacts in the third dimension, which in turn provides an incentive to process developers to advance the manufacturing domains.

System-level focus drives SINAM research from conceptual design to process development to product integration. To ensure SINAM's research agenda will successfully lead to the 3D-nano-manufacturing platform, we emphasize the role of proof-of-concept testbeds, which helps to transform lab science into industrial applications. These testbeds will act as *focal points* of the IRGs for project planning and supply a framework for team and industry partners to work together, gaining a better understanding of the system. We will continually employ these testbeds to gauge the balance of research efforts, and to focus on critical issues to achieve our vision.

Education

A recent report from the Council of Competitiveness, "The Quiet Crisis", points to the current serious workforce crisis in the high technology sector. According to this report, a quarter of the current science and engineering workforce will retire by the end of this decade. In addition, this workforce no longer mirrors the national profile. These are critical issues, made all the more serious by the paradigm shift in science and technology to the nanoscale. The crisis produced by the discontinuity between the national need and current profile of U.S. scientists and engineers will be conceivably amplified by the coming revolution in nano-manufacturing.

SINAM identifies its educational mission in addressing critical high technology work force needs from K-12 school to university graduate level, through its innovative education program. Prior to its first launching in the summer of 2004, SINAM's Nano-Manufacturing Summer Academy (NMSA) program is recruiting high school and undergraduate students around the country. Among the total of 14 applicants, 5 female students and 1 Hispanic/Latino student have submitted their applications. SINAM researchers are working with Center X to develop the course module for high school science teachers. The Graduate Young Investigator (GYI) Program provides graduate students an excellent experience for the student to be a "driver and director" in research and will also endow them with an interdisciplinary research spirit. Four new courses have been developed under the sponsorship of SINAM and two other courses have been expanded to include materials from SINAM's research collaborations.

Outreach

To build awareness of the opportunities and impact of nano-manufacturing, we are currently working with *California Science Museums* and the *California State Economic Strategy Panel*. We are prepared to work through engineering organizations such as ASME, SME, and IEEE in organizing symposia.

Reference:

[1] Further information about this project can be found at http://www.sinam.ucla.edu