Center for Scalable and Integrated Nanomanufacturing

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NSF has awarded major support to establish the Center for Scalable and Integrated NanoManufacturing (SINAM). SINAM is targeting a new nanomanufacturing 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. The nanomanufacturing technologies to be developed by SINAM promises to find applications in diverse industries, including computing, telecommunications, biomedicine, and homeland security. Located at the University of California at Los Angeles (UCLA), SINAM involves five other partner institutions: the University of California-Berkeley, Stanford University, the University of California-San Diego, the University of North Carolina at Charlotte, and HP Labs.

SINAM's research will be focused among several core nanomanufacturing technologies, including the Plasmonic Imaging Lithography and Ultramolding Imprint Lithography aiming toward critical resolution of 1-10nm and the hybrid top-down and bottom-up technologies to achieve massively parallel integration of heterogeneous nanoscale components into higher-order structures and devices. To make the innovative nanomanufactuing processes commercially viable, SINAM will develop system engineering strategies to scale-up the nanomanufacturing technologies with high throughput and high yield.

Top-down nanomanufacturing

Amazingly, surface plasmons at visible frequencies can have wavelengths down to nanometers. SINAM will develop a revolutionary approach, Plasmonic Imaging Lithography (PIL). In PIL, surface plasmon optics convert free space waves into surface waves, thus allowing unprecedented resolution of 1-10nm in the final optical image. SINAM will develop 3D nanomanufacturing based on layer-by-layer PIL approach for various materials and structures. The preliminary feasibility of plasmonic lithography with 150 nm resolution has been demonstrated in Fig. 2. [2]

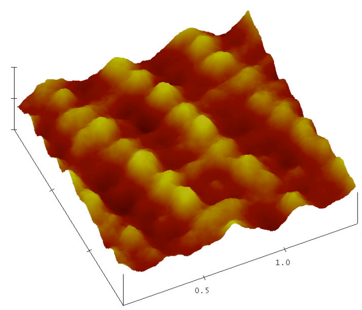

Fig 2. AFM image of a dot array pattern fabricated by PIL with 150 nm resolution.

In addition, an ultra molding and imprinting (UMIL) technology is proposed which 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

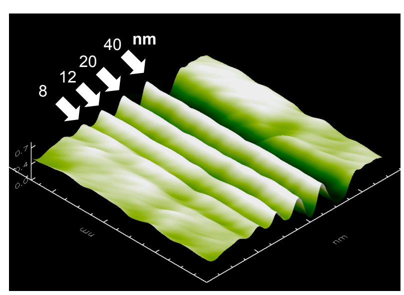

Fig 3. The UMIL process using a selectively etched Si/SiGe superlattice as a master to achieve 4 nm resolution.

superlattice, leaving the silicon fins as an imprinting mold. The advantage of the 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. As shown in Fig. 3, the preliminary results of the 4-8 nm imprinted feature has been demonstrated. [3]

Hybrid Top-down and Bottom-up manufacturing
Concurrent to the development of top-down nanomanufacturing technology, SINAM will develop a unique technology, Hybrid Top-down and Bottom-up Process (HTBP) for *massively parallel* integration of *heterogeneous* nano components into higher-order structures and devices. HTBP assembles the nano components, namely nano-LEGOs, into a defined pattern; then forms a stable structure by anchoring the nano-LEGOs. Depending on designed functionalities, the nano-LEGOs can be in the form of nano-wire, quantum dots, DNA, protein, and other functional entities.

HTBP technology has distinct advantages. First, it provides a massive parallel assembly of nano-LEGOs with a high production rate, in addition to the ability to organize the nanostructures into a desired pattern. Second, HTBP can integrate heterogeneous nanostructures. Third, it allows precise control over the destiny of the nano-LEGOs, therefore minimizing the generation of defects commonly found in self-assembly. Finally, HTBP promises a multi-scale assembly technique by linking the dimensions from nano and micro to macro world (Fig 4). Therefore, HTBP has the potential to lead to cost-effective manufacturing of more complex structures.

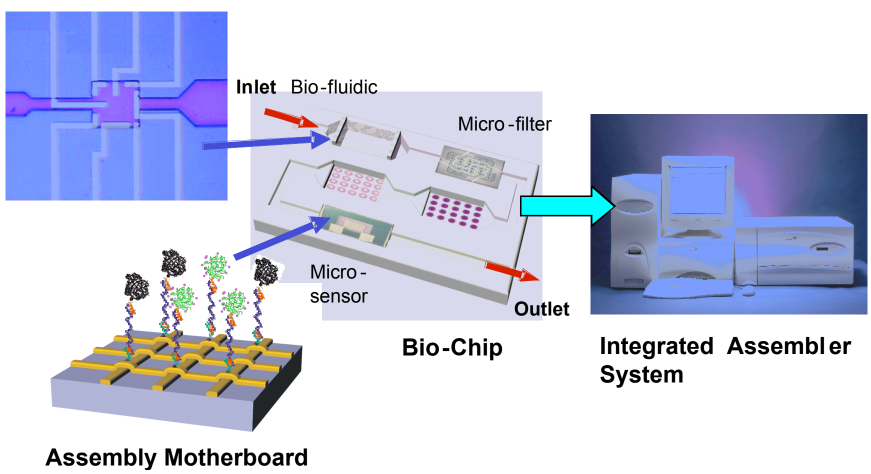

Fig 4. Integrated assembler system will bridge the multifunctional nano-LEGOs onto bio-MEMS devices and lead to scalable and cost effective manufacturing at macro-world.

System Engineering and Design for Nanomanufacturing
SINAM research will be driven by a strong system focus with the emphasis on manufacturability, scalability, and reliability. All our concepts will first have to withstand such system oriented scrutiny. This IRG will develop strategies for the nanomanufacturing system and the design process. SINAM will develop the manufacturing cluster tool concept to build an integrated manufacturing system that integrates the individual process modules such as PIL, UMIL, and FAPNA. Critical challenges such as precision control and metrology will be addressed. An innovative concurrent design and nano-CAD platform will be developed to reduce the prototyping cycle, and enhance the

scalability. SINAM will investigate the key factors in both design and manufacturing for reliability, and this effort will be jointly pursued in partnership with Sandia National Laboratory's reliability group. We will also establish an engineering test-bed for prototype development in 2D and 3D nanomanufacturing and for scale-up studies.

SINAM will develop a novel design interface: 3D nano-CAD (Fig. 5). This interactive computer aided design approach will allow efficient interactions between product design and process development. First, the initial 3D nano-structures will be integrated with the materials' properties to build a 3D geometrical model. Then the fabrication simulators and performance simulators will be employed to predict the device performances. After fabrication, the nano-structures' performance are characterized and compared with the simulation predictions by the nano-CAD simulators. This comparison will create feedback to the designer as guidance towards the final optimization of *material selection, geometric configuration,* and *process control parameters* of the 3D nano-structures.

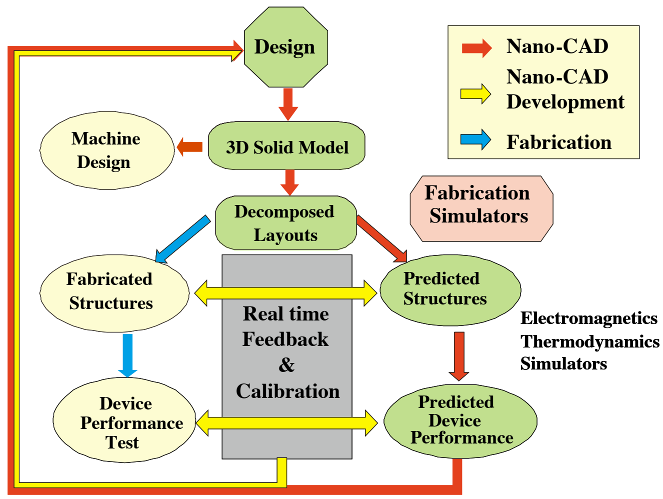

Fig 5. 3D nano-CAD development.

Education and Outreach

SINAM identifies its educational mission in addressing critical high tech work force needs, through an integrated education program with SINAM's research. SINAM will take special efforts with California schools to reach out to minority and female students as follows: (1) Grades 7-12 Discover Nanotechnology: Traditionally, K-12 education rarely offered any exposure to engineering. SINAM researchers will create an inquiry module on Nanotechnology for this community. (2) Nanomanufacturing Summer Academy will provide a 10-week summer training for undergraduates students, K-12 grade school teachers and students. We plan to develop an introductory course of Nanomanufacturing at SINAM. (3) "Graduate Young Investigator (GYI)" and Industrial Internships for Graduate Students: We will experiment with a novel concept. We will award a small grant to the best proposal from graduate students who not only propose innovative ideas, but who involve in the proposed research with at least two faculty members from different fields. This will provide an excellent experience for the GYI as a "driver and boss" in research and will also endow them with an interdisciplinary research spirit. (4) SINAM will actively build a Nanomufacturing Graduate Internship Program with our industrial partners from *SINAM Industrial Consortium*. SINAM will work with *California Science Museums* and the *California State Economic Strategy Panel* to build awareness of the opportunities and impact of nanomanufacturing.

References (10 point font)

[1] For further information about this project link to http://www.sinam.ucla.edu or email SINAM@microlab.seas.ucla.edu.
[2] Werayut, S., Sun, C., Zhang, X., et al, "Photolithography Using a Plasmonic Lens", in preparation.
[3] Chen, Y., "Fabrication of molecular electronic circuit by imprinting", (2002).U. S. Patent 6432740.