

## **Part II: Self-assessment - goal statement**

## ***Self-assessment - Goal Statement***

### **Hao Yan**

I joined the Department of Chemistry and Biochemistry & Center for Single Molecule Biophysics at the Biodesign Institute in Fall 2004 as an Assistant Professor. Before coming to ASU, I was an Assistant Research Professor in the Department of Computer Science at Duke University for 3 years. Since the first day of joining ASU, I committed myself to become the finest teacher-scholar. This self-assessment summarizes my past achievements in research and teaching and my long-term career aspirations. It is divided into three sections: 1) achievements as a scholar; 2) achievements as a teacher; 3) long-term career aspirations.

#### **1) Achievements as a scholar**

##### **Main facts:**

*Honors & Awards:* Recipient of the National Science Foundation Career award, the Air Force Office of Scientific Research Young Investigator Award, and the Arizona Technology Enterprise Innovator of Tomorrow Award.

*Awarded Research Funding:* Served as principal investigator for six federally sponsored projects and as co-principle investigator for three other federally sponsored projects. Total funding attributed to my research group: ~\$2,587,033.

*Publications:* Journal publications: 50 (29 since joining ASU). Book chapters: 6.

*Invited Talks:* 46 (33 since joining ASU).

*Patents and Patent Disclosures Filed:* 11 (10 since joining ASU).

*Graduate Students Advised:* 6 (all of them have passed the Ph.D candidate oral examination).

*Postdoc Research Associates Advised:* 3 (2 at ASU).

*Served as conference program committee member:* 5 times.

*Served as panelist for federal funding agency:* 7 times.

##### **Summary of Achievements:**

My research interests center on self-assembly of nanostructures, particularly using DNA as an assembly element. I use this new technology to develop molecular motors, sensors and templates for more complex nanostructural systems and biotechnology applications. My other research interests also include developing designer multi-component and multi-functional nanoparticle systems for applications in personalized medicine. My research program is supported by a diverse source of federal funding agencies, including NSF, NIH, ONR and AFOSR. (Please refer to the *Curriculum Vitae* for a detailed summary of my research activities.)

DNA based nanotechnology is a burgeoning field of interdisciplinary research that crosses the path from chemistry, physics, computer science, biology and material science. The ultimate goal of our research is to achieve complex chemical systems through DNA directed molecular self-assembly. We use this technology to create new ligands, sensors and novel materials. DNA is an ideal material for this purpose due to its innate ability to self-assemble into highly ordered structures based on simple Watson-Crick base pairing rules. The fabrication of DNA nanostructures begins with the designed assembly of single stranded DNA into small building block materials called tiles. DNA tiles are then able to further self-assemble into larger arrays with distinct topological and geometric features using sticky-end cohesions. DNA nanostructures assembled in this fashion can be modified in a number of ways to

contain functional materials with useful biological and electronic properties. This ‘bottom up’ approach has enormous value in the development of “molecular printboards” with resolution far exceeding current nanolithographic methods.

Since joining ASU, I assembled a productive research group including 6 graduate students and 2 Postdocs. I was invited by the editor of the prominent *Science* magazine to write a perspective article<sup>22\*</sup>, highlighting the challenges and opportunities in the field of DNA based nanotechnology. I also wrote another review article<sup>38</sup> which is published in *ChemPhysChem* summarizing the state of the art research advances made in DNA nanotechnology. To date, my coworkers and I have published 50 journal articles in high impact scientific journals in the field of chemistry. The following sections briefly highlight our main contributions to the field of DNA nanotechnology.

We have constructed a novel DNA nanostructure known as a cross structure<sup>15</sup>. This nanostructure has a 4-fold symmetry which promotes its self-assembling into tetragonal 2D lattices containing periodical square cavities. This paper has been cited more than 200 times and has inspired other researchers in the field to create DNA nanostructures, but with analogous strand connections with 3-star and 6-star motifs.

We have succeeded in using self-assembled DNA nanostructures to direct the assembly of nanoparticles into different array configurations<sup>17,29,31</sup>. We are among the first groups to achieve experimental demonstration of DNA templated 2D gold nanoparticle arrays using 1:1 DNA/gold conjugation<sup>29</sup>. Self-assembly of controllable nanoparticle architectures presents exciting opportunities in nanoelectronics and nanophotonics applications. In an NSF supported collaborative project with Profs. S. Lindsay, D. Gust and R. Diaz at ASU, we are now aiming to use DNA directed self-assembly technology to construct photonic antennas for molecule photovoltaic devices.

We have made significant progress in the use of DNA nanoscaffolds to direct the assembly of protein molecules<sup>15,17,25,26,28,43,48</sup>. We are the first group to demonstrate the use of aptamers to organize proteins into DNA tiling arrays<sup>26</sup>. Due to the easy adaptability of aptamer sequences into DNA tiles, it is now possible to organize a large variety of proteins using this technology. We have, for the first time, used self-assembled 2D signaling aptamers for biosensing applications<sup>39</sup>. This work represents a new direction of using DNA based self-assembly for biological applications. We have now constructed barcoded nanoarrays through combinatorial DNA tile self-assembly and demonstrated their applications in multiplexed biosensing<sup>42</sup>.

A key goal of DNA nanotechnology is to be able to self-assemble molecular print-boards in which individual nodes represent addressable locations for imprinting molecular functionality. In one paper we have constructed a generic ‘molecular pegboard’ where individual proteins are positioned at specific locations with controlled nanometer scale spacing<sup>28</sup>. In another paper, we devised a novel strategy to assemble finite size symmetric arrays<sup>27</sup>. In this work, we discovered a new rule that symmetry of the tile array can be utilized to reduce the number of tiles to assemble finite size DNA nanoarrays. Supported by NIH, we are currently using self-assembled fully addressable DNA tile arrays for gene expression detection.

In earlier designs of self-assembled DNA tiling arrays, people frequently observed several micrometer long ribbons or tubes. To investigate the mechanisms of DNA tube formation, we recently designed a new family of rectangular shaped DNA tiles and systematically studied the effects of the tile dimension variables, orientation of the tiles, flexibility of the tiles and strength and flexibility of the

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\* Note: Please refer the numbering of all the reference citations to the publication section of my CV

connection points for DNA tube formations<sup>32</sup>. Our findings provide new insights to the DNA tube assembly mechanisms.

A pivotal challenge in nanoscience is to bridge the gap between the top-down and bottom-up methods. We have recently achieved exciting progress in aligning self-assembled DNA nanotubes into micro-scale patterned 2D networks<sup>46</sup>, by combining soft-lithography with DNA self-assembly. We also demonstrated that such networked DNA nanotubes are functional for directed self-assembly of proteins, quantum dots and DNA targets.

My other interests in DNA nanotechnology involve constructing molecular motors that could be used for controlled chemical reactions and biosensing. Along this direction, we have designed and achieved a 2-state DNA lattice, which displays expand/contract motion switched by DNA nanoactuators<sup>14</sup>. This is the first example of incorporating DNA nanomechanical devices into 2D lattices. We have also designed an addressable molecular tweezer device and demonstrated its use to control the chemical coupling reactions triggered by DNA signals<sup>35</sup>.

In collaboration with Prof. D. Seo, we have recently devised and demonstrated a new strategy<sup>44</sup> to achieve water-soluble CdSe/ZnS core-shell quantum dots through a facile one-step functionalization of core CdSe particle. This method avoids a ligand exchange step and preserves the photoluminescence properties of the quantum dots for biomolecular conjugations. We are now aiming to integrate this technology with structural DNA nanotechnology to achieve addressable surface chemistry and functionalization of nanoparticles, which is a currently a grand challenge in material science and nanotechnology.

My contribution to the scientific community is further illustrated by an extensive record of invited talks around the world, my activity as a program committee member for international conferences, my participation as a panelist for federal funding agencies and my service as a reviewer for scientific journals (please see CV for details). These activities have allowed me to think about new directions of our research, to establish new collaborations and to seek new funding opportunities.

I am also actively involved in departmental service. I have served on the departmental seminar committee, departmental septannual review committee and faculty search committee. I have also gained considerable experience and personal fulfillment by serving the public.

## **2) Achievements as a teacher**

### **Main facts:**

*Graduate Students Advised: 6*

*Served as Committee Member for Graduate Students not in my group: 32 students*

*Undergraduate Students Mentored: 6*

*High School Students Mentored: 4*

*New Courses Developed: 2 (CHM598 Nucleic Acid and Nanobiotechnology, CHM460 Biological Chemistry).*

### **Summary of Achievements:**

I have a strong commitment to teaching at ASU. My teaching interests include: creating an interactive environment in undergraduate and graduate courses that allow students to participate in class discussions; developing graduate courses that integrate research advances in cutting edge interdisciplinary research; mentoring and inspiring students for original thinking both in research and in class; and continuing our NSF supported efforts in developing an outreach program to local high school

students.

In team-teaching with Prof. J. Chen, we designed from scratch a new graduate course titled “Nucleic Acids and Nanobiotechnology”. This class was taught in Fall 2004 and Spring 2006. It attracted a relatively large number of graduate students. I was impressed by the students’ enthusiasm to learn about new advancements in nanobiotechnology. In this class, students had the opportunity to explore the most recent research literature in this emerging field and to gain a thorough view of this field. The curriculum involved round table discussions on how nanotechnology will impact our life in the future. We also implemented a mini-grant writing section in the class so that students have the opportunity to learn how to write a research proposal. At the end of the semester, we had a proposal review panel where students divided into two groups and review the other groups’ proposals. Students truly enjoyed such learning experience and they appreciated the instructor’s efforts of implementing innovative teaching methods into a class. I continued to teach this class by myself in Spring 2007.

In spring 2006, I also co-taught another graduate course with Prof. P. Fromme titled “Advanced Topics in Biochemistry”. In my section, instead of giving lectures, I distributed materials for round table discussions. Every student had the opportunity to openly express his or her views and thoughts about a biochemical mechanism. I found this teaching strategy very effective. Student feedback indicates that they remember more after the class compared to continuous lecturing by the instructor. I will continue this approach in my future teaching activities.

In Fall 2006, I developed a new undergraduate course titled “Biological Chemistry”. This course was designed for chemistry majors who are interested in fundamental knowledge in Biochemistry. I strived to create an interactive atmosphere to allow students to think in the class, to use physical models and animations to allow students to visualize the basic concepts.

Supported by NSF Career award, my outreach activities were directed towards the dissemination of basic concepts in nanobiotechnology to high schools. We prepared lessons that provide students with the opportunity to integrate concepts from biology, physics, math, and chemistry. This outreach program aimed at raising the level of understanding of science techniques in nanobiotechnology that might be somewhat familiar to students through the media, while increasing the awareness of their impact on society, and fulfilling the students’ natural curiosity about cutting edge research.

### **3) Long-term career aspiration**

In the last decade, nanotechnology has seen many exciting advancements. The future of nanotechnology relies on our capability to deliver useful applications. In the area of directed molecular self-assembly, our ability to assemble complex chemical systems is improving but we are only at an early stage demonstrating its applications. Unlimited opportunities exist in creating self-assembling systems for biosensing, molecular photovoltaics and designer ligands. I will continue to explore new aspects and pursue use-inspired research in this area. On the other hand, directed self-assembly provides a great platform to systematically investigate distance-dependent physical properties of a large variety of molecules that is yet to be explored. I am also interested in using DNA nanoscaffolds to assemble biomolecules for metabolic engineering. The goal is to construct artificial enzymatic networks for biocatalysis. While maintaining high enthusiasm in DNA based nanotechnology research, I will expand our research program to new directions, such as integrating the exquisite power of addressability of DNA nanotechnology with nanoparticles to achieve controlled synthesis of multi-component and multi-functional nanomaterials for biomedical applications.

While sustaining a productive research program, I will continue to commit myself to high quality teaching and mentoring. Taking advantage of being a scientist in an interdisciplinary field, I will continue to bring new knowledge produced in cutting edge research to our students.