

Mechanics Modeling for Advanced Technology

Problem

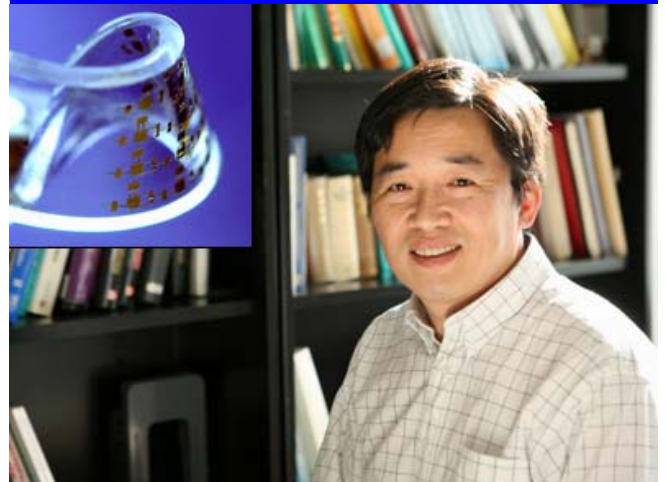
Advanced technologies have many important applications to infrastructures, such as stretchable electronics for reliability assessment, flexible and transparent silicon solar cells for energy efficiency. Mechanics plays a critical role in the development of the scientific and engineering foundations for these advanced technologies. One example is high performance electronics and optoelectronic systems that are reversibly stretchable/compressible. The goal of this group is to develop mechanics models for advanced technology (e.g., transfer printing, stretchable electronics, flexible silicon solar cell, electronic-eye camera).

Approach

These systems combine high quality electronic materials, such as aligned arrays of silicon nanoribbons and other inorganic nanomaterials, with ultrathin and elastomeric substrates, in multilayer neutral mechanical plane designs and with 'wavy' structural layouts. Such approaches, guided by detailed mechanics models, enable diverse classes of integrated circuits as well as highly integrated optoelectronics systems with well-developed electronic materials, whose intrinsic brittle, fragile mechanical properties would otherwise preclude their use in such applications. Analytical and finite element method simulations of the mechanics play a central role in the development, not only to reveal the fundamental physics, but also to provide a set of practical strategies for the construction of the devices.

Core Competencies

- Mechanics of stretchable electronics
- Mechanics of flexible silicon solar cells
- Mechanics of transfer printing



Yonggang

electronic devices on a hemispherical surface, so that they can take images much like those captured by the human eye. The new system eliminates some of the aberrations caused by current camera designs and improves the quality of captured images. The group and collaborators have also developed a silicon photo-voltaic device that is flexible and transparent. Its flexibility enables it to be mounted onto curved surfaces (such as clothes, auto bodies, outside walls of buildings and structures), while its



reliability is much better than the polymer based photo-voltaic devices. All these will significantly boost the increase of solar energy use in our daily lives.

Impact

The work of this group has been reported by many popular media such as ABC, BBC, Chicago Tribune, Discover Magazine, MSNBC, New York Times, Newsweek, Reuters, United Press International,

Selected Publications

1. Khang et al., "A stretchable form of single crystal silicon for high performance electronics on rubber substrates," *Science* **311**, 208-212, 2006
2. Meitl et al., "Transfer printing by kinetic control of adhesion to an elastomeric stamp," *Nature Materials*, **5**, 33-38, 2006.
3. Sun et al., "Controlled buckling of semiconductor nanoribbons for stretchable electronics," *Nature Nanotechnology* **1**, 201-207, 2006.
4. Jiang et al., "Finite deformation mechanics in buckled thin films on compliant supports," *PNAS* **104**, 15607-15612, 2007.
5. Kim et al., "Stretchable and foldable silicon integrated circuits," *Science* **320**, 507-511, 2008.
6. Kim et al., "Materials and non-coplanar mesh designs for integrated circuits with linear elastic responses to extreme mechanical deformations," *PNAS* **105**, 18675-18680, 2008.
7. Ko et al., "A hemispherical electronic eye camera based on compressible silicon optoelectronics," *Nature* **454**, 748-753, 2008.
8. Yoon et al., "Flexible arrays of monocrystalline silicon solar cells for micro-optic concentrator designs," *Nature Materials* **7**, 907-915, 2008.

Current Research Team Members:

- Jian Wu (post-doc research associate)
- Jianliang Xiao (Ph.D. Candidate)
- Shuodao Wang (Graduate student)

Recent Graduates:

- Duc Ngo (Ph.D. 2009) Now post-doc at CalTech.
- Jizhou Song (Ph.D. 2008) Now assistant professor at Univ. of Miami.
- Xue Feng (postdoc, 2007) Now associate professor at Tsinghua Univ., China.
- Henry Tan (research scientist, 2007) Now senior lecturer at Univ. of Aberdeen, UK.
- Hanqing Jiang (research scientist, 2006) Now assistant professor at Arizona State Univ.
- Liying Jiang (postdoc, 2006) Now assistant professor at Univ. of West Ontario, Canada
- Bin Liu (postdoc, 2004) Now associate professor at Tsinghua Univ., China
- Shaoxing Qu (Ph.D., 2004) Now associate professor at Zhejiang Univ., China.

Current Research Collaborations:

- Univ. of Illinois: Professor John Rogers.
- Univ. of Miami: Professor Jizhou Song.
- Inst. of High Performance Computing (Singapore): Drs. Yongwei Zhang and Zhuangjian Liu.

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Contact: Yonggang Huang
y-huang@northwestern.edu

<http://www.civil.northwestern.edu/people/huang.html>