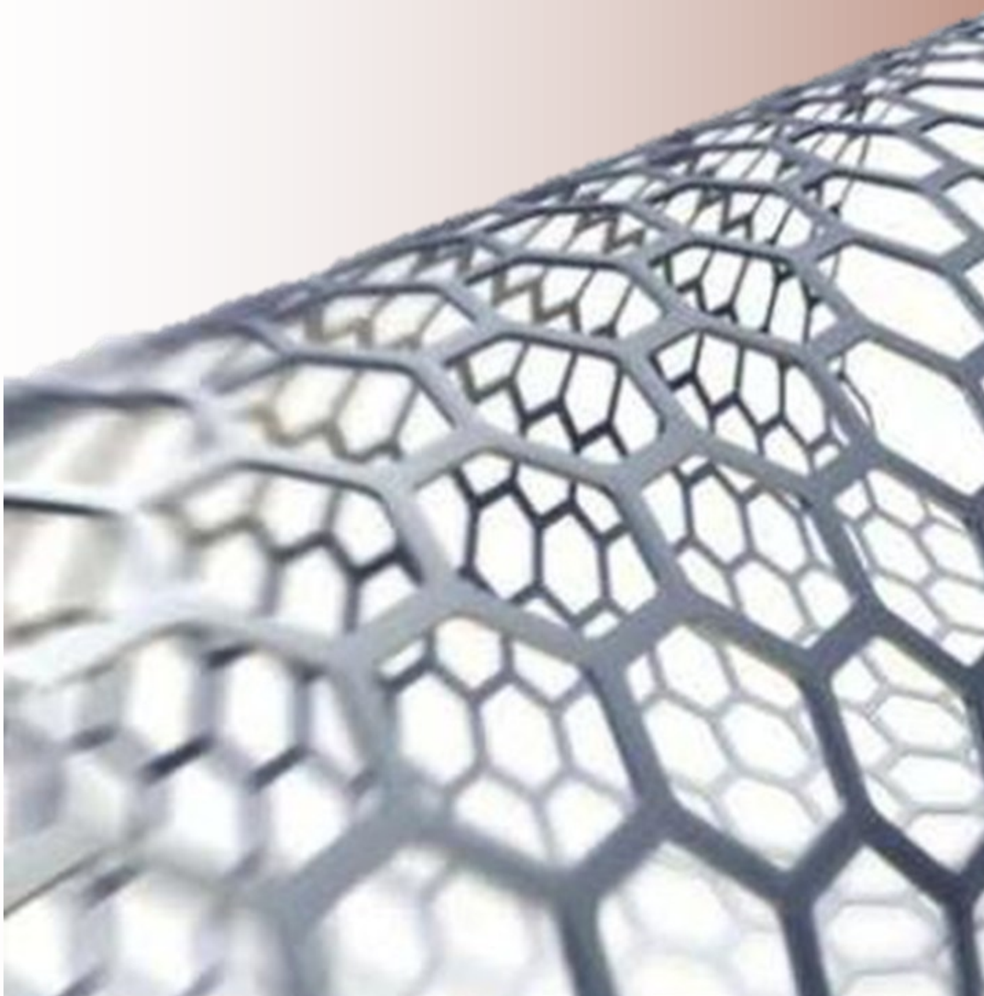
April 2012 Issue

IEEE NTC NEWSLETTER



Inside this issue:

President's Column

It is a great pleasure and privilege for me to serve this year as President of the IEEE Nanotechnology Council (NTC). Today, nanotechnology has become a ubiquitous presence in almost every conceivable technology of societal relevance. At the same time, the great success of nanotechnology is also its greatest challenge for the field and for the NTC, in terms of its broad scope and industrial base. As the representative entity within IEEE responsible for nanotechnology, the NTC must play a central role in helping to define the field in terms of its core principles and defining characteristics. My goals for the IEEE NTC are first and foremost, to increase the participation of the leading nanotechnology scientists and engineers in the NTC, and engage them in NTC efforts. Second is to establish the IEEE International Conference on Nanotechnology (IEEE Nano), the flagship conference for the NTC, as the leading international nanotechnology conference, with strong support from the NTC technical committees in defining its direction. While continuing the present upward growth in leadership and prestige of flagship journals such as the IEEE Transactions on Nanotechnology, the NTC needs to also look towards new publication venues such as open access, online journals for rapid dissemination of information in the field. The NTC will continue to engage in partnership with its member IEEE societies through joint conferences and publications, while reaching out to non-IEEE nanotechnology related organizations representing the broad scientific fields supporting nanotechnology. Finally, the NTC will look for new opportunities in rapidly growing fields such as energy, where nanotechnology will play a key role. I am very excited about the future of nanotechnology as many of the great scientific advances of the past three decades in the field translate into a myriad of new technological applications enabling the nanotechnology revolution.

Stephen M. Goodnick (M 1987; SM 1990; F 2004 (M 1987; SM 1990; F 2004) received the B.S. degree in engineering science from Trinity University, San Antonio, TX, in 1977, and the M.S. and Ph.D. degrees in electrical engineering from Colorado State University, Fort Collins, in 1979 and 1983, respectively. He was an Alexander von Humboldt Fellow with the Technical University of Munich, Munich, Germany, and the University of Modena, Modena, Italy, in 1985 and 1986, respectively. He was a faculty member from 1986 to 1997 with the Department of Electrical and Computer Engineering at Oregon State University, Corvallis, Oregon, and served as Chair and Professor of Electrical Engineering with Arizona State University, Tempe, from 1996 to 2005. He served as Deputy Dean for the Ira A. Fulton School of Engineering during 2005-2006, served as Associate Vice President for Research for Arizona State University from 2006-2008, Director of the Arizona Initiative for Renewable Energy from 2007-2010, and presently serves as Deputy Director of ASU Lightworks. He currently serves as President (2012-2013) of the IEEE Nanotechnology Council, and as President of IEEE Eta Kappa Nu Electrical and Computer Engineering Honor Society Board of Governors, 2011-2013. He served as board member and President for the Electrical and Computer Engineering Department Heads Association (ECEDHA) from 2001-2006, and was the recipient of the Robert M. Janowiak Outstanding Leadership and Service Award, Electrical and Computer Engineering Department Heads Association in 2008. He has published over 350 journal articles, books, book chapters, and conference proceeding, and is a Fellow of IEEE (2004) for contributions to carrier transport fundamentals and semiconductor devices.

Editor's Column

In this first newsletter of 2012, I would like to welcome Stephen Goodnick to his new position as the President of NTC. I look forward to working with him to bring you exciting news on nanotechnology in general and NTC in particular. The newsletter will, certainly, support Dr. Goodnick's efforts in making IEEE publications more accessible, and information more readily available. To this end, future issues of the newsletter will provide detailed information on NTC technical committees. NTC technical committees play a crucial role in advancing work in their respective fields of specialization by defining direction of conferences and organizing special sessions on topics of interest. Their responsibilities have a great impact on the future success of NTC, and I encourage our readers to be actively involved in one of these committees. In this issue, you will find an introductory article on carbon nanotube (CNT) field emission devices. This informative piece is written by Dr. Changkun Dong from Wenzhou University, China. Dr. Dong has worked at the fore-front of CNT-based field emission devices for more than 10 years; formerly as a scientist in Xintek, then as a professor at Wenzhou University. His short article brings us up-to-speed on this well known field in three pages! I am sure you will enjoy the reading.

IEEE Nanotechnology Council

NTC Newsletter Editing Team (University of Waterloo, Canada)

IEEE Advancing Technology for Humanity

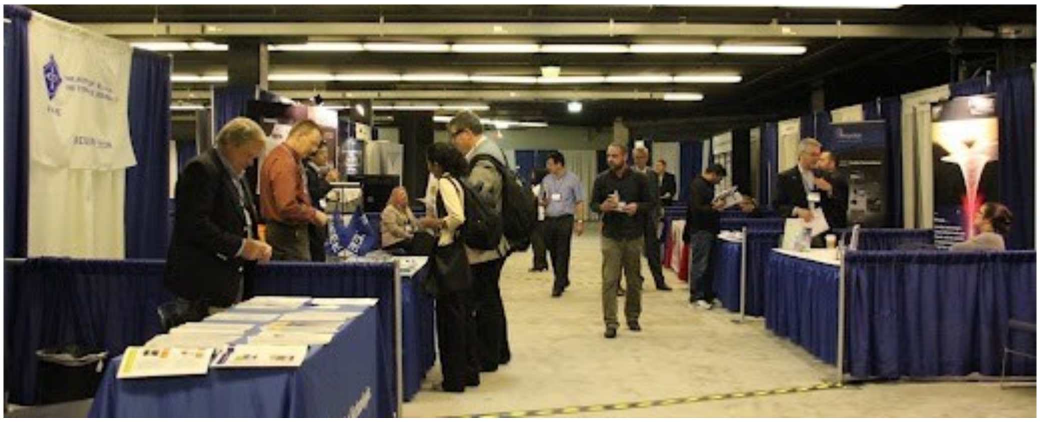
NANO 2011
August 15-18, 2011 • Portland, Oregon, USA

IEEE NANO Nanotechnology Council®

Another successful IEEE NANO 2011 with 465 attendees (plus exhibitors and sponsors), 289 oral papers that included 60 invited papers, 60 sessions, 21 technical tracks and over 100 poster papers!

IEEE NTC Awards Ceremony – the Banquet Hall

Chairman James E. Morris addressing the gathering



IEEE Nano 2011 Awardees:
From Left to right: Dr. Wen Li, Dr. Aristides Requisha, Dr. Chennupati Jagadish, IEEE President Dr. Ning Xi and Dr. Meyya Meyyappan

Celebrating the 10th Anniversary of the IEEE Nanotechnology Conference

IEEE NTC Nanotechnology Awards to be presented at IEEE NANO 2012 in *Birmingham, England*

Pioneer Award in Nanotechnology:

Joseph W. Lyding

Department of Electrical and Computer Engineering,

University of Illinois, 1406 W. Green Street, Urbana, IL 61801

Email: lyding@illinois.edu

"For advances in atomic resolution nanofabrication and discovery of the giant deuterium isotope effect and its application to CMOS technology."

Distinguished Service Award:

Ning Xi

Department of Electrical and Computer Engineering,

Michigan State University, East Lansing, MI 48824

Email: xin@egr.msu.edu

"For dedicated and distinguished service to IEEE NTC as an Elected Officer"

Early Career Award in Nanotechnology:

Sayeef Salahuddin

Department of Electrical Engineering and Computer Science,

University of California, Berkeley, CA 94720-1758

Email: sayeef@eecs.berkeley.edu

"For contributing to the understanding of the physics of hetero-interfaces in nanostructures and investigating their use for energy efficient applications"

IEEE TRANSACTIONS ON NANOTECHNOLOGY

A PUBLICATION OF THE IEEE NANOTECHNOLOGY COUNCIL

The IEEE Transactions on Nanotechnology (TNANO) publishes novel and important results in science and engineering at the nanoscale. It focuses on nanoscale devices, materials, systems, and applications, and on their underlying science. It is an interdisciplinary journal that covers all areas of nanotechnology. The hardcopy version is published bi-monthly, but accepted papers are published on the web as soon as they are submitted in final form.

TNANO publishes Research Letters, Regular Papers, and Correspondence Items. Research Letters must not exceed three printed pages. They are subject to the same thorough review process as Regular Papers, but receive priority treatment. A Research Letter that is accepted without major revisions is expected to be published on the web within 4 to 6 weeks of its initial submission.

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April 2012 Issue

Applications of carbon nanotube field emission in high power vacuum electronic devices

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High power vacuum electronic devices (HPVEDs), including traveling wave tubes (TWTs), x-ray tubes, and electric propulsion & charge control devices, are critical components in communication, space tasks, defense, security, and many other fields [1-5]. Developments of compact and efficient electron sources are a key factor to make high quality HPVEDs. Thermionic cathodes, the most commonly used electron sources, operate properly only when they are heated to high temperatures. The nature of the thermionic cathodes creates many technical difficulties for the devices, including low emission current density, poor energy efficiency, long turn-on time, sensitivity to "poisoning" materials at elevated temperatures, limited operating lifetime, and device design restrictions associated with the high temperature operation. Therefore, employments of cold cathode technique will have significant impacts on any electron source related applications, especially for high power vacuum electronic devices. Field emissions have been studied for many decades in related fields, and inspiring development has been achieved, i.e., field emitter array (FEA) based instruments.

Spindt-type FEA cathodes of about 1 mm^2 in area had been used in a traveling wave tube (TWT) and were able to generate a 50mA electron beam under density of 6.3A/cm^2 [6, 7], the cathode lifetime and the ability to scale its size to 10 or 100 cm^2 are still under concern. Other field emission cathodes using nanostructured diamond and graphite nanopowders have also been developed, but the electric fields required by all of these materials to get useful current densities are too high to be applicable in microwave tubes.

Carbon nanotubes (CNTs) are superior electron field emitters due to unique structure, excellent chemical and physical properties, as well as mechanical strength [8-10]. Compared with other field emitters, CNTs have lower threshold fields for emission (~1-2V/μm) and are capable of emitting at extremely high current densities. The experiments have shown that an emission current of as high as 1μA can be drawn from one carbon nanotube tube [11] and emission current density of 54A/cm^2 [12] has been demonstrated from carbon fiber films. Some CNT based prototype vacuum electronic devices, such as the flat panel display, field emission lighting element [13,14], luminescent lamp [15], and field emission x-ray [16,17], have been successfully fabricated. In the past decade, tremendous efforts have been made internationally on the developments of CNT field emission based HPVEDs [18-21], and European countries are working closely on this field. These efforts indicate that CNT based field emission cathodes are promising candidates for replacing the thermionic cathodes to make the next generation vacuum electronic amplifiers.

Despite the excellent field emission properties of carbon nanotubes, many materials issues have limited their eventual utilization in the vacuum electronic devices. For example, due to the poor uniformity of the nanotube films, in particular the films with large emission areas, the emissions are mainly originated from some "hot spots" on the films. These "hot spots" prevent the majority of carbon nanotubes in the cathodes from emitting electrons and therefore high emission current cannot be readily obtained from large emission areas. The overall performance of the cathode also depends on the density of CNTs.

When the nanotube density on the cathode is too high, the screening effect prevents nanotubes from emitting electrons. However, when the density is too low, the emission area is not fully utilized. Theoretical simulation has suggested that the ideal distance between the adjacent nanotubes in a CNT cathode should be about twice the length of the nanotubes.

Therefore, the key to employ the CNT field emission on HPVEDs is to produce high quality cathodes with high emission density and stable long lifetime under high emission and anode voltages. Currently, CNT cathodes are mainly produced by direct CVD deposition or the post-synthesis deposition. For the CVD method, normally a catalyst film is deposited or produced on the substrate surface, from which catalyst particles in nanometer dimension are formed under high temperatures [22]. There are mainly two post-synthesis deposition methods: electrophoresis deposition (EPD) and Screen Printing, where CNTs are blended with metal particles and curing materials. The mixture is adhered on the conducting substrate followed by high temperature sintering. This method is capable of producing large emitting surface with good uniformity. Typical requirements for the cathode in HPVEDs include: electron current of 100 mA-20A, current density of 100 mA/cm^2-10A/cm^2, anode voltage of 100 kV or higher, and a lifetime of more than 10,000 hours. Scientists are working on the improvements of CNT field emitters to meet these tough technical requirements. Working in the pulse mode, the CNT cathodes have been successfully employed in the high flux x-ray micro CT [17]. It is still a challenge to operate the CNT cathodes for HPVEDs in continuous mode stably with adequate lifetime.

Some key factors influencing the high energy operation of CNT cathodes are related with the adhesion of CNTs with the substrates. First, for above cathode production methods, nanotubes normally bind with the substrates through catalysts & curing materials. After multiple high temperature processing and operation steps, including high T degassing and Joule heating from the electron emission, the emitting film may parch and lose tight binding with the substrate, resulting in the film parts falling off. This not only weakens the cathode emission capability, it also worsens the system vacuum, damaging the emission performance further. Secondly, the contacts between nanotubes and the substrate & solidification layer normally have larger thermal loss due to contacting resistances, depending on the emitter production and processing processes, which not only influence the cathode conducting performance, but also speed up the aging of the emitting film. Therefore, strong binding and low contacting resistances between CNTs and substrates & solidification layers are crucial factors for high quality CNT field emitters. A study suggested that the degradation and failure is due to mechanical failure from the tensile loading of the emitter under the applied electric field for low field ($<4V/\mu m$) emissions, or to the resistive heating at the contact that is enhanced by the mechanical stress for high current emissions [23].

Improvement of the nanotube-substrate binding remains a central issue on the CNT cathode developments. One promising technique is to synthesize the CNT emitters directly on the catalytic substrates by chemical vapor deposition [24,25]. From the growth, nanotubes contact with the substrate directly, avoiding the intermediate catalyst solidification layer, which could improve the electronic transmission and mechanical performances. Some post CNT film synthesis processes are also attempted, i.e., applying the microwave treatment to improve the CNT film on the Si substrate [26], and employing the nano welding technique to enhance the CNT adhesion from the EPD process [27]. Several groups attempted to add another metal layer between the catalyst metal and the substrate to improve the cathode emission performance [28-30]. With the progresses on CNT synthesis, field emitter development, post emitter development processing, and in situ processing of emitters & devices, it is highly possible that the CNT field emission based high power vacuum electronic devices will meet the tough technical and market challenges in the foreseeable future.

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About the author:

Changkun Dong received the B.S. degree in electronic engineering from Southeast University at Nanjing, China, in 1985 and Ph.D. degree in physics from Old Dominion University at Norfolk, Virginia, in 2003. He joined the Lanzhou Institute of Physics, China, in 1985. He worked in Jefferson Lab at Newport News, Virginia, during 1996-2003 as visiting scholar and Ph.D. candidate. He joined Xintek, Inc. (then Applied Nanotechnology, Inc.) at Chapel Hill, North Carolina, in 2003 as research scientist. He is currently the professor of physics and Director of the Institute of Micro-Nano Structure & Optoelectronics at Wenzhou University, China.

Professor Dong has over 40 research publications and patents in the fields of nano technology, vacuum instrumentation, and cryogenic engineering. He worked on the synthesis and field emission applications of carbon nanotubes since 1998. He and collogues in Jefferson Lab developed first carbon nanotube field emission based ionization gauge. Collaborating with scientists in the University of North Carolina at Chapel Hill, he led several federal sponsored nano projects on the developments of carbon nanotube field emission based X-ray devices， scanning TEM electron sources, low power consumption ion thruster, as well as electron source for electron beam ion traps.

Student's Corner

April 20, 2012
10th Annual IEEE Workshop on Microelectronics and Electron Devices. Boise, ID.
http://www.ewh.ieee.org/r6/boise/wmed2012/WMED2012.html

April 25-27, 2012
Symposium on Design, Test, Integration and Packaging of MEMS/MOEMS. Cannes, France
http://cmp.imag.fr/Conferences/dtip/dtip2012/

May 30 - June 01, 2012
International Conference on Integrated Circuit Design and Technology. Austin, TX.
http://www.icicdt.org/index.asp

June 10-11, 2012
IEEE Silicon Nanoelectronics Workshop. Honolulu, HI.
http://www-device.eecs.berkeley.edu/snw/2012_IEEE_Silicon_Nanoelectronics_Workshop/General_Information.html

June 18 - 21, 2012
15th Annual Nanotech 2012. Santa Clara, CA.
http://www.techconnectworld.com/Nanotech2012/

August 6-9, 2012
IEEE Photonics Society International Conference on Optical MEMS and Nanophotonics. Banff, Alberta, Canada
http://www.mems-ieee.org/

August 20-23, 2012
12th International Conference on Nanotechnology. Birmingham, UK.
http://ieeenano2012.org/

April 2012

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