Qing Cao

Curriculum Vita

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PROFESSIONAL APPOINTMENTS

University of Illinois at Urbana-Champaign: Urbana, IL. *October 2018-prsent*

Associate Professor of Materials Science and Engineering, with affiliated appointments in Chemistry, Electrical and Computer Engineering, and Seitz Materials Research Lab

IBM Thomas J. Watson Research Center: Yorktown Heights, NY. *February 2009−October2018*

Research Staff Member

EDUCATION

University of Illinois at Urbana-Champaign Ph.D. degree in Materials Chemistry, January 2009.

Nanjing University, China B.S. degree in Chemistry, June 2004.

AWARDS AND HONORS

- President's Distinguished Faculty Hire of the University of Illinois 2018
- Millennium Fellow of the Atlantic Council 2017
- I.B.M. Pat Goldberg Memorial Best Paper Award 2017
- I.B.M. Master Inventor Recognition 2016
- 35 Innovators under 35 (*TR35*) by MIT Technology Review 2016
- U.S. Frontiers of Engineering by National Academy of Engineering 2019, 2016
- I.B.M. Research Division Award 2016
- "*All-Star Alumni*" of Forbes 30 Under 30s 2016
- I.B.M. Corporation Outstanding Technical Achievement Award 2015
- Forbes Magazine "*30 under 30*" list of rising stars in Science and Healthcare 2012
- I.B.M. Corporation Invention Achievement Award (fifteen times) 2009-2017

SELECTED PUBLICATIONS (* indicates corresponding author)

40 papers in journals including *Nature, Science, Nature Nanotechnology, Nature Electronics, Nature Communications, Science Advances*, etc. 4 conference proceedings. 3 book chapters.

1) Y. Zhang, J-S. Cui, K.-Y. Chen, S.-H. Kuo, J. Sharma, R. Bhatta, Z. Liu, A. Ellis-Mohr, F-F. An, J-H. Li, Q. Chen, K. D. Foss, H. Wang, Y-M. Li, A. M. McCoy, G. W. Lau, and **Q. Cao***, "A Smart Coating with Integrated Physical-Antimicrobial and Strain-Mapping Functionalities for Orthopedic Implants," *Science Advances*. 9, eadg7393 (2023).

    Highlighted by *NSF Discovery Files*: Smart surgical implant coatings.

    ***Materials Today*:** Antibacterial coatings take the strain on orthopedic implants.

    ***Nanowerk*:** Smart surgical implant coatings provide early failure warning while preventing infection.

    ***AZO Materials*:** "Smart" polymer foil coating for orthopedic implants.

***ASM International*:** Bug-inspired coating could make for better bone and joint implants.
***Bone Zone*:** Smart implant coating inspired by insect wings creates a buzz.
Diagnostics World: Nature-inspired orthopedic implant coating kills bacteria, monitors strain.
***Science Techniz*:** Smart implant coatings revolutionise modern medicine.

2) J.S. Cui, F.F. An, J.C. Qian, YX. Wu, L. L. Sloan, S. Pidaparthy, J.-M. Zuo, and **Q. Cao***, "CMOS-Compatible Electrochemical Synaptic Transistor Arrays for Deep Learning Accelerator," *Nature Electron*. 6, 292–300 (2023).
Highlighted by *Science Daily*: First silicon integrated ECRAM for a practical AI accelerator.
***TechXplore*:** Researchers achieve the first silicon integrated ECRAM for a practical AI accelerator.
***Today Headline*:** OpenAI's ChatGPT costs $100k per day to run; accelerators could help.
***Hackster*:** Electrochemical RAM, Bonded on Silicon Chips, Could Boost Edge AI.
***Electronics for You*:** Low Cost ECRAM For AI Accelerators.
3) **Q. Cao***, J. Tersoff, D. B. Farmer, Y. Zhu, and S.-J. Han, "Carbon nanotube transistors scaled to a 40-nanometer footprint," *Science* 356(6345), 1369-1372 (2017).
Highlighted by *Science*: Scientists use carbon nanotubes to make the world's smallest transistors.
***IEEE Spectrum*:** Carbon nanotubes reduce transistor footprint to forty nanometers.
***Neue Zürcher Zeitung* (*New Journal of Zurich*):** Nanoröhren schalten auf engstem raum.
***Next Big Future*:** IBM has made carbon nanotubes transistors smaller and faster than silicon.
***Science News Magazine*:** The incredible shrinking transistor just got smaller.
***Physics Today*:** Carbon nanotube transistors are scaled down to record size.
4) **Q. Cao***, S.-J. Han, J. Tersoff, A. D. Franklin, Y. Zhu, Z. Zhang, G. S. Tulevski, J.-S. Tang, and W. Haensch, "End-bonded contacts for carbon nanotube transistors with low, size-independent resistance," *Science* 350(6256), 68-72 (2015).
Highlighted by *New York Times*: IBM scientists find new way to shrink transistors.
***Time*:** IBM's new research could mean much more powerful computers.
***Fortune*:** IBM aims to replace silicon transistors with carbon nanotubes to keep up with Moore's Law.
***Wall Street Journal*:** Carbon nanotube valley?
***Reuters*:** IBM research breakthrough paves way for post-silicon future with nanotube electronics.
***Forbes*:** Carbon nanotubes are getting closer to making our electronic devices obsolete.
***MIT Technology Review*:** IBM reports breakthrough on carbon nanotube transistors.
***IEEE Spectrum*:** IBM solves nanotube transistor's big shrinking problem.
***Nature Nanotechnology*:** Less is Moore.
5) **Q. Cao*,** S.-J. Han, G. S. Tulevski, Y. Zhu, D. D. Lu, and W. Haensch, "Arrays of single-walled carbon nanotubes with full surface coverage for high-performance electronics," *Nature Nanotechnol.* 8, 180-186 (2013).
Highlighted by *Nature Nanotechnology*: Nanotube arrays made to order.
***MRS Bulletin*:** High-performing transistors fabricated with single-walled carbon nanotube arrays.
***PhysOrg*:** Densest array of carbon nanotubes paves way toward post-silicon technology.
***Nanotechweb*:** CNT arrays make record-breaking transistors.
6) **Q. Cao***, S.-J, Han, and G. S. Tulevski, "Fringing-field dielectrophoretic assembly of ultrahigh-density semiconducting nanotube arrays with a self-limited pitch," *Nature Commun*. 5, 5071 (2014).

7) **Q. Cao**, H.-S. Kim, N. Pimparkar, J. P. Kulkarni, C. Wang, M. Shim, K. Roy, M. A. Alam, and J. A. Rogers*, "Medium-scale carbon nanotube thin-film integrated circuits on flexible plastic substrates," *Nature* 454, 495-500 (2008).
   Highlighted by *Chemical and Engineering News*: Flexible circuits from carbon nanotubes.
   ***Chemistry World*:** Nanotube mesh boosts plastic electronics.
   ***MIT Technology Review*:** Bendable nanotube circuits.
   ***R&D Magazine*:** The way to close a "nanonet" is by cutting it into pieces.
   ***Science Daily*:** "Nanonet" circuits closer to making flexible electronics reality.
   ***Nanotechweb*:** Flexible CNT circuits move on.

SELECTED PATENTS

Over 50 patents and patent applications in areas ranging from novel logic devices to solar cells to nanofabrication to memory technologies and flexible electronics. Three most recent ones.

1) **Q. Cao**, F-F. An, C.-J. Wang, V.-H. Pham, and C. Matranga, "2D Amorphous carbon film assembled from graphene quantum dots," U.S. Patent Application No. 63/167,422
2) **Q. Cao**, and Y. Zhang, "Nanostructured bactericidal polymer foil," U.S. Patent Application No. US 63/07223.
3) **Q. Cao** and J.S. Cui, "Solid-state electrochemical random access memory (ECRAM) and methods of making and operating a solid-state ECRAM," U.S. Patent Application No. 63/434,627.

SELECTED INVITED TALKS

>20 invited talks and keynote lectures in conferences and research institutions.

1) "Electrochemical transistor array for deep learning accelerators," at *2023 Non-volatile memory technology symposium (NVMTS)*, Imec, Belgium, August 2023.
2) "Two-dimensional amorphous carbon prepared from solution as dielectrics for nanoelectronics," at the *Materials Research Society 2022 Fall Meeting*, Boston, MA, November 2022.
3) "Future nanoelectronics based on carbon nanomaterials," at *241st ECS Meeting*, Vancouver, BC, Canada, May 2022.
4) "Replacing silicon with carbon nanotubes in logic transistors", keynote lecture at the *15th IEEE International Conference on Nano/Micro Engineered & Molecular Systems*, September 20, 2020.
5) "New materials and devices beyond silicon and field-effect transistors," at *2020 TMS Annual Meeting & Exhibition*, San Diego, CA, February 2020.
6) "Carbon nanotube transistor technology for extremely-scaled logic devices" at Center for Nanoscale Systems, Harvard University, Boston, MA, October 2017.
7) "Carbon nanotube for extremely scaled logic transistors to the end of the technology roadmap" at the *18th International Conference on the Science and Application of Nanotubes and Low-dimensional Materials*, Belo Horizonte, Brazil, June 2017.
8) "High-performance logic electronics based on carbon nanotubes for 5-nm technology node and beyond" at the *Materials Research Society 2016 Fall Meeting*, Boston, MA, November 2016.
9) "Carbon nanotube transistor technology for scaling beyond Si CMOS" at the *48th International Conference on Solid State Devices and Materials (SSDM)*, Tsukuba, Japan, September, 2016.

PROFESSIONAL ACTIVITIES AND SERVICES

Journal reviewer for *Science*, *Science Advances*, *Nature Nanotechnology, Nature Electronics, Nature Catalysis, Nature Communications, Advanced Materials, ACS Nano, Nano Letters, Chemistry of Materials, ACS Applied Materials & Interfaces, Nanoscale, Physical Review Applied, Applied Physics Letters, Journal of Applied Physics, Nanotechnology, IEEE Electron Device Letters, IEEE Transactions on Nanotechnology, Chemical Communications, Physical Chemistry Chemical Physics, Journal of Materials Chemistry, Environmental Science and Technology.*

Deputy Editor of *Science Advances* 2018-present

Meeting Chair of *2020 Virtual MRS Spring/Fall Meeting & Exhibit*

Grant Reviewer for *US National Science Foundation* and *Applied Research Grant of Hong Kong.*

Technical Program Committee Member: *IEEE 12th International Conference on Nanotechnology*

CURRENT EXTERNAL RESEARCH SUPPORT AS PI

1. Grant title: GCR: Synthetic Neurocomputers for Cognitive Information Processing
   Source: National Science Foundation
   Total costs: $3,600,000 10/2021-09/2026.
2. Grant title: Developing coal-derived carbon nanomaterials as the switching media in non-volatile memory devices for neuromorphic and edge-computing applications
   Source: Department of Energy-National Energy Technology Laboratory
   Total Award Amount: $810,000 10/2020-12/2023.
3. Grant title: Smart Coating with Biomimetic Antimicrobial Nanostructures and Strain-Mapping Electronics for Osseointegrated Prostheses to Address Infection and Mechanical Failure Risks
   Source: Department of Defense Congressionally Directed Medical Research Programs
   Total Award Amount: $724,841 09/2021-08/2024.
4. Grant title: Preparation and Assembly of Carbon Nanotube/Silica Core-Shell Nanowires to Realize High-Density and Well-Aligned Nanotube Arrays with Uniform and Tunable Pitch
   Source: Taiwan Semiconductor Manufacturing Company (TSMC)
   Total costs: $450,000 01/2022-12/2024.
5. Grant title: Two-Dimensional Amorphous Carbon with Tunable Atomic Structures As A Novel Dielectric Material for Advanced Electronic Applications
   Source: National Science Foundation
   Total costs: $700,490 12/2021-11/2024.
6. Grant title: IUCRC Phase I: University of Illinois at Urbana-Champaign (UIUC): Center for Aggressive Scaling by Advanced Processes for Electronics and Photonics (ASAP)
   Source: National Science Foundation
   Total costs: $750,000 01/2023-12/2027.

Full Publication List

PEER-REVIEWED JOURNAL PUBLICATIONS (* indicates corresponding author)

1) Y. Zhang, J-S. Cui, K.-Y. Chen, S.-H. Kuo, J. Sharma, R. Bhatta, Z. Liu, A. Ellis-Mohr, F-F. An, J-H. Li, Q. Chen, K. D. Foss, H. Wang, Y-M. Li, A. M. McCoy, G. W. Lau, and Q. Cao*, "A Smart Coating with Integrated Physical-Antimicrobial and Strain-Mapping Functionalities for Orthopedic Implants," Science Advances. 9, eadg7393 (2023). **[Highlighted by the NSF Discovery Files, ScienceDaily, Nanowerk, Materials Today, Tech Explorist, ASM International, Science Magazine,Today Headline, MedicalXpress, Press Trust of India, The Pioneer, AZO Materials, The Engineer, and more]**
2) J.S. Cui, F.F. An, J.C. Qian, YX. Wu, L. L. Sloan, S. Pidaparthy, J.-M. Zuo, and **Q. Cao***, "CMOS-Compatible Electrochemical Synaptic Transistor Arrays for Deep Learning Accelerator," Nature Electron. 6, 292–300 (2023). **[Highlighted by ScienceDaily, Science Magazine, TechXplore, Today Headline, Electronics for You, News8Plus, Semiconductor Engineering, and more]**
3) **Q. Cao***, "Carbon Nanotube Transistor Technology for More-Moore Scaling," *Nano Res*. 14, 3051-3069 (2021) [**Invited Review**].
4) Y. D. Xu, G. G. Zhao, L. Zhu, Q.H. Fei, Z. Zhang, Z. Y. Chen, F. F. An, Y. Y. Chen, Y. Ling, P. J. Guo, S. H. Ding, G. L. Huang, P.-Y. Chen, **Q. Cao**, and Z. Yan, "Pencil–paper on-skin electronics," *Proc. Natl. Acad. Sci. U.S.A.* 117 (31) 18292-18301 (2020).
5) **Q.Cao***, "Better radio-frequency transistors with nanotubes," *Nature Electron.* 2, 495–496 (2019).
6) J.-S. Tang, **Q. Cao**, G. S. Tulevski, K. A. Jenkins, L. Nela, D. B. Farmer and S.-J. Han, "Flexible CMOS integrated circuits based on carbon nanotubes with sub-10 ns stage delays," *Nature Electron.* 1, 191-196 (2018).
7) L. Nela, J.-S. Tang*, **Q. Cao**, G. S. Tulevski, and S.-J. Han*, " Large-area high-performance flexible pressure sensor with carbon nanotube active matrix for electronic skin," *Nano Lett.* 18 (3), 2054-2059 (2018).
8) **Q. Cao***, J. Tersoff, D. B. Farmer, Y. Zhu, and S.-J. Han, "Carbon nanotube transistors scaled to a 40-nanometer footprint," *Science* 356(6345), 1369-1372 (2017).
9) A. L. Falk*, K.-C. Chiu, D. B. Farmer, **Q. Cao**, J. Tersoff, Y.-H. Lee, Ph. Avouris, and S.-J. Han, "Coherent plasmon and phonon-plasmon resonances in carbon nanotubes," *Phys. Rev. Lett.* 118(25), 257401 (2017).
10) J.-S. Tang*, **Q. Cao**, D. B. Farmer, G. S. Tulevski, and S.-J. Han, "High-performance carbon nanotube complementary logic with end-bonded contacts," *IEEE Trans. Electron Devices* 64(6), 2744-2750 (2017).
11) J. Wang, T. D. Nguyen, **Q. Cao***, Y. L. Wang, M. Y. C. Tan, and M. B. Chan-Park*, "Selective surface charge sign reversal on metallic carbon nanotubes for facile ultra-high purity nanotube sorting," *ACS Nano* 10(3), 3222-3232 (2016).
12) **Q. Cao***, S.-J. Han, J. Tersoff, A. D. Franklin, Y. Zhu, Z. Zhang, G. S. Tulevski, J.-S. Tang, and W. Haensch, "End-bonded contacts for carbon nanotube transistors with low, size-independent resistance," *Science* 350(6256), 68-72 (2015). **[Highlighted by *New York Times*, *Time, Fortune, Daily Mail, Wall Street Journal, Washington Post, Forbes, Reuters, MIT Technology Review, IEEE Spectrum, EE Times, Wired, CNET, Engadget, PC Magazine, PC World, Physorg, Nature***

***Nanotechnology, Information Week*, and more]**

13) **Q. Cao***, J. Tersoff, S.-J. Han, and A. V. Penumatcha, “Scaling of device variability and subthreshold swing in ballistic carbon nanotube transistors,” *Phys. Rev. Appl.* 4(2), 024022 (2015). **[Featured in Editor’s Suggestion]**
14) **Q. Cao***, S.-J. Han, A. V. Penumatcha, M. M. Frank, G. S. Tulevski, J. Tersoff, and W. E. Haensch, “Origins and characteristics of the threshold voltage variability of quasiballistic single-walled carbon nanotube field-effect transistors,” *ACS Nano* 9(2), 1936 (2015). **[Highlighted by *Nanotechweb*]**
15) G. S. Tulevski*, A. D. Franklin, D. Frank, J. M. Lobez, **Q. Cao**, H. Park, A. Afzali, S.-J. Han, J. B. Hannon, and W. Haensch, “Toward high-performance digital logic technology with carbon nanotubes,” *ACS Nano* 8 (9), 8730-8745 (2014).
16) **Q. Cao***, S.-J, Han, and G. S. Tulevski, “Fringing-field dielectrophoretic assembly of ultrahigh-density semiconducting nanotube arrays with a self-limited pitch,” *Nature Commun*. 5, 5071 (2014).
17) **Q. Cao***, S.-J. Han, “Single-walled carbon nanotubes for high-performance electronics,” *Nanoscale* 5(19), 8852-8863 (2013). **[Invited Feature Article]**
18) **Q. Cao*,** S.-J. Han, G. S. Tulevski, Y. Zhu, D. D. Lu, and W. Haensch, “Arrays of single-walled carbon nanotubes with full surface coverage for high-performance electronics,” *Nature Nanotechnol.* 8(3), 180-186 (2013). **[Highlighted by *Nature Nanotechnology*, *MRS Bulletin*, *PhysOrg*, and *Nanotechweb*]**
19) **Q. Cao***, S.-J. Han, G. S. Tulevski, A. D. Franklin, and W. Haensch, “Evaluation of field-effect mobility and contact resistance of transistors that use solution-processed single-walled carbon nanotubes,” *ACS Nano* 6(7), 6471-6477 (2012).
20) A. D. Franklin*, G. S. Tulevski, S.-J. Han, D. Shahrjerdi, **Q. Cao**, H.-Y. Chen, H. -S. P. Wong, and W. Haensch, “Variability in carbon nanotube transistors: improving device-to-device consistency,” *ACS Nano* 6(2), 1109-1115 (2012).
21) **Q. Cao**, O. Gunawan, M. Copel, K. B. Reuter, S. J. Chey, V. R. Deline, and D. B. Mitzi*, “Defects in Cu(In,Ga)Se_2 chalcopyrite semiconductors: a comparative study of material properties, defect states, and photovoltaic performance,” *Adv. Energy Mater.* 1(5), 845-853 (2011). **[Frontispiece feature article, Highlighted by *Materials Views*]**
22) X. Ho, L. Ye, S. V. Rotkin, **Q. Cao**, S. Unarunotai, S. Salamat, M. A. Alam and J. A. Rogers*, “Scaling properties in transistors that use aligned arrays of single-walled carbon nanotubes,” *Nano Lett.* 10(2), 499-503 (2010).
23) C. Kocabas, S. Dunham, **Q. Cao**, K. Cimino, X. Ho, H.-S. Kim, D. Dawson, J. Payne, M. Stuenkel, H. Zhang*, T. Banks, M. Feng, S. V. Rotkin and J. A. Rogers*, “High-frequency performance of submicrometer transistors that use aligned arrays of single-walled carbon nanotubes,” *Nano Lett.* 9(5), 1937-1943 (2009).
24) N. Pimparkar, **Q. Cao**, J. A. Rogers*, and M. A. Alam*, “Theory and practice of “stripping” for improved on/off ratio in carbon nanonet thin film transistors,” *Nano Research* 2(2), 167-175 (2009).
25) **Q. Cao** and J. A. Rogers*, “Ultrathin films of single-walled carbon nanotubes for electronics and sensors: a review of fundamental and applied aspects,” *Adv. Mater.* 21(1), 29-53 (2009). **[Featured in *Advances in Advance,* Most Accessed Article in December, 2008]**
26) **Q. Cao** and J. A. Rogers*, “Random networks and aligned arrays of single-walled carbon nanotubes

for electronic device applications," *Nano Research* 1(4), 259-272 (2008). **[Invited Review]**

27) **Q. Cao**, H.-S. Kim, N. Pimparkar, J. P. Kulkarni, C. Wang, M. Shim, K. Roy, M. A. Alam, and J. A. Rogers*, "Medium-scale carbon nanotube thin-film integrated circuits on flexible plastic substrates," *Nature* 454(7203), 495-500 (2008). **[Highlighted by *Chemical and Engineering News*, *Chemistry World, MIT Technology Review, Semiconductor International, R&D Magazine, Science Daily, Small Times, Science Centric, Ars Technica, I-Micronew Magazine, Nanotechweb, Physorg*, and more]**
28) M. J. Schultz, X.-Y. Zhang, S. Unarunotai, D.-Y. Khang, **Q. Cao**, C.-J. Wang, C.-H. Lei, S. McLaren, J. Soares, I. Petrov, J. S. Moore*, and J. A. Rogers*, "Crosslinked, conjugated carbon monolayers: films, balloons, tubes and pleated Sheets," *Proc. Natl. Acad. Sci. U. S. A.* 105(21), 7353-7358 (2008). **[Highlighted by *Chemistry World and Nanowerk*]**
29) S. J. Kang, C. Kocabas, H.-S. Kim, **Q. Cao**, M. A. Meitl, D.-Y. Khang, and J. A. Rogers*, "Printed multilayer superstructures of aligned single-walled carbon nanotubes for electronic applications," *Nano Lett.* 7(11), 3343-3348 (2007).
30) **Q. Cao**, M.-G. Xia, C. Kocabas, M. Shim, S. V. Rotkin*, and J. A. Rogers*, "Gate capacitance coupling of single-walled carbon nanotube thin-film transistors," *Appl. Phys. Lett.* 90(2), 023516 (2007).
31) N. Pimparkar, **Q. Cao**, S. Kumar, J. Y. Murthy, J. A. Rogers, and M. A. Alam*, "Current-voltage characteristics of long-channel nanobundle thin-film transistors: a 'bottom-up' perspective," *IEEE. Electron. Device Lett.* 28(2), 157-160 (2007).
32) E.-L. Gui, L.-J. Li*, P. S. Lee, A. Lohani, S. G. Mhaisalkar, **Q. Cao**, S. J. Kang, J. A. Rogers, N. C. Tansil, and Z. Gao, "Electrical detection of hybridization and threading intercalation of deoxyribonucleic acid using carbon nanotube network field-effect transistors," *Appl. Phys. Lett.* 89(23), 232104 (2006).
33) **Q. Cao**, M.-G. Xia, M. Shim, and J. A. Rogers*, "Bilayer organic-inorganic gate dielectrics for high-performance, low-voltage single-walled carbon nanotube thin-film transistors, complementary logic gates and p-n diodes on plastic substrates," *Adv. Func. Mater.* 16(18), 2355-2362 (2006). **[Cover feature article]**
34) **Q. Cao**, Z.-T. Zhu, M. G. Lemaitre, M.-G. Xia, M. Shim, and J. A. Rogers*, "Transparent flexible organic thin-film transistors that use printed single-walled carbon nanotube electrodes," *Appl. Phys. Lett.* 88(11), 113511 (2006). **[Selected in *Virtual Journal of Nanoscale Science & Technology* published by APS]**
35) **Q. Cao**, S.-H. Hur, Z.-T. Zhu, Y.-G. Sun., C.-J. Wang, M. A. Meitl, M. Shim, and J. A. Rogers*, "Highly bendable, transparent thin-film transistors that use carbon-nanotube-based conductors and semiconductors with elastomeric dielectrics," *Adv. Mater.* 18(3), 304-309 (2006). **[Highlighted by *Chemical and Engineering News*]**
36) C.-J. Wang*, **Q. Cao**, T. Ozel, A. Gaur, J. A. Rogers, and M. Shim*, "Electronically selective chemical functionalization of carbon nanotubes: correlation between Raman spectral and electrical responses," *J. Am. Chem. Soc.* 127(32), 11460-11468 (2005).
37) F.-P. Zhang, **Q. Cao**, J.-J. Cheng, C.-H. Zhang, N. An, and S.-P. Bi*, "Electrochemical and spectrometric studies of double-strand calf thymus gland DNA denatured by Al(III) at neutral pH," *Anal. Sci.* 25(8), 1019-1023 (2009).

38) X.-F. Long, D.-S. Li, N. Wang, C.-H. Zhang, **Q. Cao**, T.-C. Xian, and S.-P. Bi*, "A novel and sensitive method for recognition and indirect determination of Al^{III} in biological fluid based on the quenching of resonance Rayleigh scattering intensities of 'Al^{III}-EV-DNA' complexing system," *Spectroc. Acta Pt. A-Molec. Biomolec. Spectr.* 69(1), 142-147 (2008).
39) Q. Miao, **Q. Cao,** and S.-P. Bi*, "Density functional theory study on the bridge structure in dimeric aluminum (III) water complexes," *J. Chem. Phys.* 121(10), 4650-4656 (2004).
40) S.-P. Bi*, C.-Y. Wang, **Q. Cao**, and C.-H. Zhang, "Studies on the mechanism of hydrolysis and polymerization of aluminum salts in aqueous solution: correlations between the 'Core-Links' Model and 'Cage-Like' Keggin-Al_{13} Model," *Coord. Chem. Rev.* 248(5), 441-455 (2004).

CONFERENCE PROCEEDINGS

1) J.-S. Tang, **Q. Cao**, D. B. Farmer, G. S. Tulevski, and S.-J. Han, "Carbon nanotube complementary logic with low-temperature processed end-bonded metal contacts," *IEDM Tech. Digest*, 5.1.1-5.1.4 (2016) [**Highlighted by *EE Times***].
2) **Q. Cao**, "*En route* toward high performance electronics based on single-walled carbon nanotubes," *Proc. SPIE 9083, Micro- and Nanotechnology Sensors, Systems, and Applications VI*, 90830M (2014).
3) D. B. Mitzi, T. K. Todorov, O. Gunawan, M. Yuan, **Q. Cao**, W. Liu, K. B. Reuter, M. Kuwahara, K. Misumi, A. J. Kellock, S. J. Chey, T. G. de Monsabert, A. Prabhakar, V. Deline, and K. E. Fogel, "Towards marketable efficiency solution-processed kesterite and chalcopyrite photovoltaic devices," in *Photovoltaic Specialists Conference (PVSC)*, 640-645 (2010).
4) **Q. Cao**, C. Kocabas, and J. A. Rogers, "Carbon nanotube for high-performance flexible electronics," *Proc. 7th Electrochem. Soc.-Int. Semi. Tech. Conf.*, 690 (2008).

BOOK CHAPTERS

1) **Q. Cao**, and S.-J. Han, "Nanoelectronics based on singled-walled carbon nanotubes," In *Nanomaterials, Polymers, and Devices: Materials Functionalization and Device Fabrication*. Kong, E.S.W. Eds. Wiley-VCH (2015).
2) C. J. Wang, and **Q. Cao**, "Thin films of single-walled carbon nanotubes for flexible electronic device applications," In *Semiconductor Nanomaterials for Flexible Technologies*, Y. G. Sun, J. A. Rogers, Eds. Elsevier (2010).
3) **Q. Cao**, C. Kocabas, M. A. Meitl, S. J. Kang, J. U. Park, and J. A. Rogers, "Single-walled carbon nanotubes for high performance thin film electronics," In *Carbon Nanotube Electronics*, A. Javey, J. Kong, Eds. Springer Verlag GmbH Co.: KG (2008).

ISSUED PATENTS

1) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "On-chip integrated temperature protection device based on gel electrolyte," U.S. Patent No. US 10546940B2.
2) **Q. Cao**, H. Deligianni, and F. Liu, "High resolution brain-electronics interface," U.S. Patent No. US 10576268.
3) **Q. Cao**, K.-G. Cheng, and J.-T. Li, "Nanoparticle structure and process for manufacture," U.S. Patent No. US 10544042B2.

4) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "Three-dimensional integration of neuro-synaptic chips," U.S. Patent No. US 10832127B2.
5) **Q. Cao**, N. Li, "Semiconductor device with a steep subthreshold slope," U.S. Patent No. US 10319847.
6) **Q. Cao**, K.-G. Cheng, and Z.-W. Li, "Piezoelectric vacuum transistor," U.S. Patent No. US 10573482B2.
7) **Q. Cao**, J.-S. Tang, and S.-J. Han, "End-bonded metal contacts on carbon nanotubes," U.S. Patent No. US 10319927B2.
8) **Q. Cao**, and S.-J. Han, "Three-dimensional integrated multispectral imaging sensor," U.S. Patent No. US 9881966B2.
9) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "Dielectric thermal conductor for passivating efuse and metal resistor," U.S. Patent No. US 9941202B2.
10) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "High density nanofludic structure with precisely controlled nano-channel dimensions," U.S. Patent No. US 9679897B1.
11) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "Single-electron transistor with self-aligned coulomb blockade," U.S. Patent No. US 10032897B2.
12) **Q. Cao**, K.-G. Cheng, Z.-W. Li, and F. Liu, "FDSOI with on-chip physically unclonable function," U.S. Patent No. US 10026648B2.
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14) **Q. Cao**, K.-G. Cheng, and Z.-W. Li, "Vertically integrated nanotube and quantum dot LED for active matrix display," U.S. Patent No. US 10026912B1.
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