Tianxiang Nan, Ph.D.

Assistant Professor
Institute of Microelectronics
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PROFESSIONAL APPOINTMENT

12/2019-present	Assistant Professor Institute of Microelectronics Tsinghua University
12/2018-12/2019	Postdoctoral Research Associate Laboratory of Prof. Dan Ralph Department of Physics Cornell University
11/2015-12/2018	Postdoctoral Research Associate Laboratory of Prof. Chang-Beom Eom Department of Materials Science and Engineering University of Wisconsin Madison

EDUCATION

09/2011-08/2015	Ph.D. in Electrical Engineering Northeastern University, Boston, USA Thesis Advisor: Prof. Nian Sun
09/2007-07/2011	B.E. in Microelecronics University of Electronic Science and Technology of China, Sichuan, China

HONORS AND AWARDS

- Thousand Youth Talent Program (2018).
- Chinese Government Award for Outstanding Self-Financed Students Abroad (2014).
- Best Student Presentation Finalists, 2014 IEEE International Magnetics Conference, Dresden, German.
- Best Student Presentation Finalists, 58th Conference on Magnetism and Magnetic Materials 2013, Denver, CO.
- Outstanding Poster Paper Award, 2013 IEEE MEMS Conference, Taipei, Taiwan.

SELECTED PUBLICATIONS (*h*-index = 25, Citations > 2300)

1. **T. Nan**, C.X. Quintela, J. Irwin, G. Gurung, D.F. Shao, J. Gibbons, N. Campbell, K. Song, S.Y. Choi, L. Guo, R.D. Johnson, P. Manuel, R.V. Chopdekar, I. Hallsteinsen, T. Tybell, P.J. Ryan, J.W. Kim, Y.S. Choi, P.G. Radaelli, D.C. Ralph, E.Y. Tsymba, M.S. Rzchowski, C.B. Eom, "Controlling spin current polarization through non-collinear antiferromagnetism", *Nature Communications, in press.*

2. **T. Nan**, Y. Lee, S. Zhuang, Z. Hu, J.D. Clarkson, X. Wang, C. Ko, H. Choe, Z. Chen, D. Budil, J. Wu, S. Salahuddin, J. Hu, R. Ramesh, N. Sun, "Electric-field control of spin dynamics during magnetic phase transitions", *Science Advances, in press.*

3. C.X. Quintela, K. Song, D.F. Shao, L. Xie, **T. Nan**, T.R. Paudel, N. Campbell, X. Pan, M.S. Rzchowski, E.Y. Tsymbal, S.Y. Choi, C.B. Eom, "Epitaxial antiperovskite/perovskite heterostructures for materials design", *Science Advances, in press.*

4. L. Guo, N. Campbell, Y. Choi, J.Kim, P.J. Ryan, H. Huyan, L. Li, **T. Nan**, J.Kang, C. Sundahl, X. Pan, M.S. Rzchowski, C.B. Eom, "Spontaneous Hall Effect enhanced by local Ir moments in epitaxial $Pr_2Ir_2O_7$ thin films", *Physical Review B* 101, 104405 (2020).

5. **T. Nan***, T.J. Anderson*, J. Gibbons, K. Hwang, N. Campbell, H. Zhou, Y.Q. Dong, G.Y. Kim, D.F. Shao, T.R. Paudel, N. Reynolds, X.J. Wang, N.X. Sun, E.Y. Tsymbal, S.Y. Choi, M.S. Rzchowski, Yong Baek Kim, D.C. Ralph, C.B. Eom, "Anisotropic spin-orbit torque generation in epitaxial $SrIrO_3$ by symmetry design", *Proceedings of the National Academy of Sciences*, 116, 16186-16191 (2019).

6. **T. Nan**, J. Hu, M. Dai, S. Emori, X. Wang, Z. Hu, A. Matyushov, L.Q. Chen, N.X. Sun, "A strain-mediated magnetoelectric-spin-torque hybrid structure", *Advanced Functional Materials*, 29, 1806371 (2019).

7. Z. Wang, C. Dong, X. Wang, M. Li, **T. Nan**, X. Liang, H. Chen, Y. Wei, H. Zhou, M. Zaeimbashi, S. Cash, N.X. Sun, "Highly sensitive integrated flexible tactile sensors with piezoresistive $Ge_2Sb_2Te_5$ thin films", *npj Flexible Electronics* 2, 17 (2018).

8. S. Emori, A. Matyushov, H. Jeon, C.J. Babroski, **T. Nan**, A.M. Belkessam, J.G. Jones, M.E. McConney, G.J. Brown, B.M. Howe, N. Sun, "Spin-orbit torque and spin pumping in YIG/Pt with interfacial insertion layers", *Applied Physics Letters* 112, 182406 (2018).

9. **T. Nan***, H. Lin*, Y. Gao, A. Matyushov, G. Yu, H. Chen, N. Sun, S. Wei, Z. Wang, M. Li, X. Wang, A. Belkessam, R. Guo, B. Chen, J. Zhou, Z. Qian, Y. Hui, M. Rinaldi, M.E. McConney, B.M. Howe, Z. Hu, J.G. Jones, G.J. Brown, N.X. Sun, "Acoustically actuated ultra-compact NEMS magnetoelectric antennas", *Nature Communications* 8, 296 (2017). **Highlighted in *Nature* News and *Science* News.**

10. M. Zhu*, **T. Nan***, B. Peng, Y. Zhang, Z. Zhou, X. Yang, W. Ren, N.X. Sun, M. Liu, "Epitaxial multiferroic heterostructures and applications", *IEEE Transactions on Magnetics* 99 (2017).

11. B. Peng*, Z. Zhou*, **T. Nan***, G. Dong, M. Feng, Q. Yang, X. Wang, S. Zhao, D. Xian, Z.D. Jiang, W. Ren, Z.G. Ye, N.X. Sun, M. Liu, "Deterministic switching of perpendicular magnetic anisotropy by voltage control of spin seorientation transition in $(Co/Pt)_3/Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ multiferroic heterostructures", *ACS Nano* 11, 4337-4345 (2017).

12. M. Li, A. Matyushov, C. Dong, H. Chen, H. Lin, **T. Nan**, Z. Qian, M. Rinaldi, Y. Lin, N.X. Sun, "Ultra-sensitive NEMS magnetoelectric sensor for picotesla DC magnetic field detection", *Applied Physics Letters* 110, 143510 (2017).

13. Q. Yang, **T. Nan**, Y. Zhang, Z. Zhou, B. Peng, W. Ren, Z. G. Ye, N. X. Sun, M. Liu, "Voltage control of perpendicular magnetic anisotropy in multiferroic $(Co/Pt)_3/PbMg_{1/3}Nb_{2/3}O_3{-}PbTiO_3$ Heterostructures", *Physical Review Applied* 8, 044006 (2017).

14. Z.G. Wang, X. Wang, M. Li, Y. Gao, Z. Hu, **T. Nan**, X. Liang, H. Chen, J. Yang, S. Cash, N.X. Sun, "Highly sensitive flexible magnetic sensor based on anisotropic magnetoresistance effect", *Advanced Materials* 28, 9370 (2016).

15. M. Liu*, **T. Nan***, J. Hu*, S. Zhao, Z. Zhou, C. Wang, W. Ren, Z. Ye, L. Chen, N.X. Sun,

"Electrically controlled non-volatile switching of magnetism in multiferroic heterostructures via engineered ferroelastic domain states", *NPG Asia Materials* 8, e316 (2016). (*equal contribution)

16. Y. Gao, X. Wang, L. Xie, Z. Hu, H. Lin, Z. Zhou, **T. Nan**, X. Yang, B.M. Howe, J.G. Jones, G.J. Brown, N.X. Sun, "Giant electric field control of magnetism and narrow ferromagnetic resonance linewidth in FeCoSiB/Si/SiO_2/PMN-PT multiferroic heterostructures", *Applied Physics Letters* 108, 232903 (2016).

17. S. Emori, **T. Nan**, A.M. Belkessam, X. Wang, A.D. Matyushov, C.J. Babroski, Y. Gao, H. Lin, N.X. Sun, "Interfacial spin-orbit torque without bulk spin-orbit coupling", *Physical Review B* 93, 180402 (2016).

18. **T. Nan**, S. Emori, B. Peng, X. Wang, Z. Hu, L. Xie, Y. Gao, H. Lin, J. Jiao, H. Luo, D. Budil, J.G. Jones, B.M. Howe, G.J. Brown, M. Liu, N.X. Sun, "Control of magnetic relaxation by electric-field-induced ferroelectric phase transition and inhomogeneous domain switching", *Applied Physics Letters* 108, 012406 (2016).

19. Z. Hu, X. Wang, **T. Nan**, Z. Zhou, B. Ma, X. Chen, J.G. Jones, B.M. Howe, G.J. Brown, Y. Gao, H. Lin, Z. Wang, R. Guo, S. Chen, X. Shi, W. Shi, H. Sun, D. Budil, M. Liu, N.X. Sun, "Non-Volatile Ferroelectric Switching of Ferromagnetic Resonance in NiFe/PLZT Multiferroic Thin Film Heterostructures", *Scientific Reports* 6, 32408 (2016).

20. Z. Zhou, S. Zhao, Y. Gao, X. Wang, **T. Nan**, N.X. Sun, X. Yang, M. Liu, "The memory effect of magnetoelectric coupling in FeGaB/NiTi/PMN-PT multiferroic heterostructure", *Scientific Reports* 6, 20450 (2016).

21. X. Yang, Z. Zhou, **T. Nan**, Y. Gao, G.M. Yang, M. Liu, N.X. Sun, "Recent advances in multiferroic oxide heterostructures and devices", *Journal of Materials Chemistry C* 4, 234 (2016).

22. X. Yang, M. Liu, B. Peng, Z.Y. Zhou, **T. Nan**, H.J. Sun, N.X. Sun, "A wide-band magnetic tunable bandstop filter prototype with FeGaB/Al_2O_3 multilayer films", *Applied Physics Letters* 107, 122408 (2015).

23. J.M. Hu*, **T. Nan***, N.X. Sun*, L.Q. Chen*, "Multiferroic magnetoelectric nanostructures for novel device applications", *MRS Bulletin* 40, 728 (2015). ***(Invited Review)***

24. **T. Nan**, S. Emori, C.T. Boone, X. Wang, T.M. Oxholm, J.G. Jones, B.M. Howe, G.J. Brown, N.X. Sun, "Comparison of spin-orbit torques and spin pumping across NiFe/Pt and NiFe/Cu/Pt interfaces", *Physical Review B* 91, 214416 (2015).

25. Z. Zhou, Q. Yang, M. Liu, Z. Zhang, X. Zhang, D. Sun, **T. Nan**, N.X. Sun, X. Chen, "Antiferroelectric Materials, Applications and Recent Progress on Multiferroic Heterostructures", *Spin* 5, 1530001 (2015). ***(Invited Review)***

26. Y. Hui, **T. Nan**, N.X. Sun, M. Rinaldi, "High resolution magnetometer based on a high frequency magnetoelectric MEMS-CMOS oscillator", *Journal of Microelectromechanical Systems* 24, 134 (2015).

27. Z. Zhou, M. Trassin, Y. Gao, Y. Gao, D. Qiu, K. Ashraf, **T. Nan**, X. Yang, S.R. Bowden, D.T. Pierce, M.D. Stiles, J. Unguris, M. Liu, B.M. Howe, G.J. Brown, S. Salahuddin, R. Ramesh, N.X. Sun, "Probing electric field control of magnetism using ferromagnetic resonance", *Nature communications* 5, 6082 (2015).

28. Z. Zhou, B.M. Howe, M. Liu, **T. Nan**, X. Chen, K. Mahalingam, N.X. Sun, G.J. Brown, "Interfacial charge-mediated non-volatile magnetoelectric coupling in $Co_{0.3}Fe_{0.7}$/$Ba_{0.6}Sr_{0.4}TiO_3$/Nb:$SrTiO_3$ multiferroic heterostructures", *Scientific Reports* 5, 7740 (2015).

29. Z. Hu, **T. Nan**, X. Wang, M. Staruch, Y. Gao, P. Finkel, N.X. Sun, "Voltage control of magnetism in FeGaB/PIN-PMN-PT multiferroic heterostructures for high-power and high-temperature applications", *Applied Physics Letters* 106, 022901 (2015).

30. S. Emori, **T. Nan**, T.M. Oxholm, C.T. Boone, J.G. Jones, B.M. Howe, G.J. Brown, D. Budil, N.X. Sun, "Quantification of the spin-Hall anti-damping torque with a resonance spectrometer", *Applied Physics Letters* 106, 022406 (2015).

31. X. Xue, Z. Zhou, B. Peng, M. Zhu, Y. Zhang, W. Ren, T. Ren, X. Yang, **T. Nan**, N.X. Sun, M. Liu, "Electric field induced reversible 180 magnetization switching through tuning of interfacial exchange bias along magnetic easy-axis in multiferroic laminates", *Scientific reports* 5, 16480 (2015).

32. M. Zhu*, **T. Nan***, M. Liu, W. Ren, Z. Zhou, N.X. Sun, "Voltage tuning of ferromagnetic resonance and linewidth in spinel ferrite/ferroelectric multiferroic heterostructures", *IEEE Magnetics Letters* 6, 1 (2015).

33. **T. Nan**, M. Liu, W. Ren, Z.G. Ye, N.X. Sun, "Voltage control of metal-insulator transition and non-volatile ferroelastic switching of resistance in VO_x/PMN-PT heterostructures", *Scientific reports* 4, 5931 (2014).

34. Y. Gao, S.Z. Zardareh, X. Yang, **T. Nan**, Z. Zhou, M. Onabajo, M. Liu, A. Aronow, K. Mahalingam, B.M. Howe, G.J. Brown, N.X. Sun, "Significantly enhanced inductance and quality factor of GHz integrated magnetic solenoid inductors with FeGaB/Al_2O_3 multilayer films", *IEEE Transactions on Electron Devices* 61, 1470-1476 (2014).

35. X. Yang, Y. Gao, J. Wu, Z. Zhou, S. Beguhn, **T. Nan**, N.X. Sun, "Voltage tunable multiferroic phase shifter with YIG/PMN-PT heterostructure", *IEEE Microwave and Wireless Components Letters* 24, 191-193 (2014).

36. **T. Nan**, Z. Zhou, M. Liu, X. Yang, Y. Gao, B.A. Assaf, H. Lin, S. Velu, X. Wang, H. Luo, J. Chen, S. Akhtar, E. Hu, R. Rajiv, K. Krishnan, S. Sreedhar, D. Heiman, B.M. Howe, G.J. Brown, N.X. Sun, "Quantification of strain and charge co-mediated magnetoelectric coupling on ultra-thin Permalloy/PMN-PT interface", *Scientific reports* 4, 3688 (2014).

37. Z. Zhou, X.Y. Zhang, T.F. Xie, **T. Nan**, Y. Gao, X. Yang, X. Wang, X.Y. He, P.S. Qiu, N.X. Sun, D.Z. Sun, "Strong non-volatile voltage control of magnetism in magnetic/antiferroelectric magnetoelectric heterostructures", *Applied Physics Letters* 104, 012905 (2014).

38. W. Liang, Z. Li, Z. Bi, **T. Nan**, H. Du, C. Nan, C. Chen, Q. Jia, Y. Lin, "Role of the interface on the magnetoelectric properties of BaTiO 3 thin films deposited on polycrystalline Ni foils", *Journal of Materials Chemistry C* 2, 708 (2014).

39. Z. Zhou, **T. Nan**, Y. Gao, X. Yang, S. Beguhn, M. Li, Y. Lu, J.L. Wang, M. Liu, K. Mahalingam, B.M. Howe, G.J. Brown, N.X. Sun, "Quantifying thickness-dependent charge mediated magnetoelectric coupling in magnetic/dielectric thin film heterostructures", *Applied Physics Letters* 103, 232906 (2013).

40. X. Yang, Y. Gao, J. Wu, S. Beguhn, **T. Nan**, Z. Zhou, M. Liu, N.X. Sun, "Dual H- and E-field tunable multiferroic bandpass filter at KU-band using partially magnetized spinel ferrites", *IEEE Transactions on Magnetics* 49, 5485-5488 (2013).

41. G. Wu*, **T. Nan***, R. Zhang, N. Zhang, S. Li, N.X. Sun, "Inequivalence of direct and converse magnetoelectric coupling at electromechanical resonance", *Applied Physics Letters* 103, 182905 (2013).

42. M. Liu, B.M. Howe, L. Grazulis, K. Mahalingam, **T. Nan**, N.X. Sun, G.J. Brown, "Voltage-impulse-induced non-volatile ferroelastic switching of ferromagnetic resonance for reconfigurable magnetoelectric microwave devices", *Advanced Materials* 25, 4886-4892 (2013).

43. X. Yang, J. Wu, Y. Gao, **T. Nan**, Z. Zhou, S. Beguhn, N.X. Sun, "Compact and low loss phase shifter with low bias field using partially magnetized ferrite", *IEEE Transactions on magnetics* 49, 3882-3885 (2013).

44. **T. Nan***, Y. Hui*, M. Rinaldi, N.X. Sun, "Self-biased 215MHz magnetoelectric NEMS resonator for ultra-sensitive DC magnetic field detection", *Scientific reports* 3, 1985 (2013).

45. X. Yang, J. Wu, S. Beguhn, **T. Nan**, Y. Gao, Z. Zhou, N.X. Sun, "Tunable bandpass filter using partially magnetized ferrites with high power handling capability", *IEEE Microwave and Wireless Components Letters* 23, 184-186 (2013).

46. M. Liu, Z. Zhou, **T. Nan**, B.M. Howe, G.J. Brown, N.X. Sun, "Voltage tuning of ferromagnetic resonance with bistable magnetization switching in energy-efficient magnetoelectric composites", *Advanced Materials* 25, 1435-1439 (2013).

47. W. Liang, Y. Ji, **T. Nan**, J. Huang, Z. Bi, H. Zeng, H. Du, C. Chen, Q. Jia, Y. Lin, "Growth dynamics of barium titanate thin films on polycrystalline Ni foils using polymer-assisted deposition technique", *ACS applied materials & interfaces* 4, 2199 (2012).

48. **T. Nan**, Z. Zhou, J. Lou, M. Liu, X. Yang, Y. Gao, S. Rand, N.X. Sun, "Voltage impulse induced bistable magnetization switching in multiferroic heterostructures", *Applied Physics Letters* 100, 132409 (2012).

49. **T. Nan**, H. Zeng, W. Liang, S. Liu, Z. Wang, W. Huang, W. Yang, C. Chen, Y. Lin, "Growth behavior and photoluminescence properties of ZnO nanowires on gold nano-particle coated Si surfaces", *Journal of Crystal Growth* 340, 83 (2012).

PATENTS

1. M. Rinaldi, N.X. Sun, **T. Nan**, & Y. Hui, "Systems and methods for magnetic field detection." International Patent No. 20,160,003,924.

2. N.X. Sun, H. Lin, & **T. Nan**, "Ultra-compact rf magnetoelectric antennas based on acoustic resonance in NEMS resonators." U.S. Application No. 62/343,801.

3. C.B. Eom, **T. Nan**, & T.J. Anderson, "5d transition metal oxides with giant spin-Hall effect for magnetic memory." U.S. Application No. 16/019,831; International Patent PCT/US2018/039696.

4. C.B. Eom, & **T. Nan**, "Non-collinear antiferromagnets for high density and low power spintronics devices." U.S. Application No. P190064US01.

BOOK CHAPTERS

1. **T. Nan**, N.X. Sun, "Progress toward magnetoelectric spintronics", in Composite Magnetoelectrics: Materials, Structures, and Applications, pp. 329, Elsevier, 2015.

2. Z. Wang, M. Li, **T. Nan**, N. Sun, " Multiferroic Sensors", in Integrated Multiferroic Heterostructures and Applications, pp. 203, John Wiley & Sons, 2019.

CONFERENCE AND SEMINAR PRESENTATIONS

3. "Anisotropic spin-orbit torque generation in epitaxial $SrIrO_3$ by symmetry design", MRS Fall Meeting 2019, Boston, MA. (***invited talk***)
4. "Anisotropic spin-orbit torque generation in epitaxial $SrIrO_3$ by symmetry design", APS March Meeting 2019, Boston, MA. (***invited talk***)
5. "Spin-Hall effect in complex materials by symmetry design", ***invited seminar*** at Department of Physics, Cornell University, 09/2018.
6. "Spin-Hall effect in complex materials by symmetry design", ***invited seminar*** at Materials Science Division, Argonne National Laboratory, 09/2018.
7. "Crystalline symmetry dependence of spin-Hall conductivity in perovskite $SrIrO_3$" 62th Magnetism and Magnetic Materials 2017, Pittsburgh, PA.
8. "Voltage control of the spin-Hall torque in a multiferroic composite" 13th Joint MMM-Intermag Conference 2016, San Diego, CA.
9. "Magnetoelectric heterostructures for spintronics and magnetic sensing", ***invited seminar*** at Department of Materials Science and Engineering, University of Wisconsin Madison, 10/2015.
10. "Integrated multiferroics for magnetic sensing, and rf antenna applications." Multiferroic Strategy Meeting, Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS), University of California, Los Angeles, 10/2015. (***invited talk***)
11. "Voltage control of spin-orbit torques in PMN-PT/CoFeB/Pt multiferroic composites probed by spin-torque ferromagnetic resonance", 2015 Materials Research Society Fall Meeting, Boston, MA.
12. "Magnetoelectric resonator for broadband magnetic field detection", 59th Magnetism and Magnetic Materials 2014, Honolulu, HI.
13. "NEMS magnetoelectric resonator for ultra-low frequency magnetic field detection", 2014 Intermag, Dresden, Germany. (***Best Student Presentation Award Finalists***)
14. "Quantification of strain and charge co-mediated magnetoelectric coupling on unltra-thin Permalloy/PMN-PT interface", 2014 Intermag, Dresden, Germany.
15. "High sensitivity magnetoelectric magnetic field sensor." 2014 International Conference of Young Researchers on Advanced Materials, Haikou, China. (***invited talk***)
16. "Self-biased 215MHz magnetoelectric NEMS resonant magnetic field sensor", 2013 Materials Research Society Fall Meeting, Boston, MA.
17. "UHF NEMS Resonant Magnetoelectric Magnetic Field Sensor." 2013 Materials Science & Technology, Montreal, Canada. (***invited talk***)
18. "Self-Biased 215MHz magnetoelectric NEMS resonator for ultra-sensitive dc magnetic field detection", 58th Magnetism and Magnetic Materials 2013, Denver, CO. (***Best Student Presentation Award Finalists***)
19. "Voltage impulse induced bistable magnetization switching in multiferroic heterostructures", 2012 Materials Science & Technology, Pittsburg, PA.

20. “Non-volatile switching of bistable magnetization in multiferroic heterostructures” 2012 Intermag, Vancouver, Canada.

PROFESSIONAL SRVICES

- Journal Referee:

Science, Physical Review Letters, Nature Communications, Nano Letters, Scientific Reports, Applied Physics Letter, Journal of Applied Physics, APL Materials, IEEE Transactions on Magnetics, Journal of Materials Science: Materials in Electronics, Physical Chemistry Chemical Physics, Applied Surface Science

- Conference Services:

Session Chair, MRS Fall Meeting 2019, EL03.06: Ferroelectrics and Metal-Insulator Transition, Boston, MA.

Session Chair, 62th Magnetism and Magnetic Materials 2017, Session AP: Ferrites and Garnets I, Pittsburgh, PA.

- Panel Reviewer:

National Science Foundation proposal review, High Frequency and Advanced Device Concepts panel, 01/2017.