Prof. CH Kees de Groot

Academic Staff

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1994-1998 Research Assistant, Philips Research Laboratories, the Netherlands
1998-2000 Research Fellow, Massachusetts Institute of Technology (MIT), USA
2000-2012 Assistant/Associate Professor, University of Southampton, U.K.
2012 onwards: Professor, University of Southampton, Southampton, U.K.

Research

Research interests

My main interest is the integration of novel nano-materials and devices with silicon electronics processing with particular emphasis on the semiconducting properties of oxides, chalcogenides, and carbides. Our recent breakthroughs in these areas includes the first 100 nm GeSbTe phase change memory by (non-aqueous) electrodeposition, SiC resistive memory with a record 9 orders of magnitude on/off ratio, and selective growth by chemical vapour deposition of thermo-electric materials Bi_2Te_3 and Sb_2Te_3.

Pushing the boundaries of e-beam lithography and Helium ion milling to create functional structures underpins much of my additional research, resulting in magneto-electronic and plasmonic devices with sub-10 nm features and ultrafast modulation of optical and dielectric properties of ITO, AZO and VO_2 by optical, electrical, and thermal methods.

Projects

- Phase Change Memory Materials via Non-Aqueous Electrodeposition into Nano-structured Templates
- Thin Film Thermo-Electric Generators
- Lead Niobate-based Tunable Dielectrics for Smart Microwave and Millimeter-wave Systems
- Electrical and picosecond optical control of plasmonic nanoantenna hybrid devices
- Radiation Effects and Reliability of Resistive Memories (RRAM)
- NiPd-Si Schottky barrier Hydrogen Sensors
- Semi-insulating Si for RF circuits
- Spintronic device physics in Si/Ge Heterostructures
- Magnetic Nanostructures
- Vertical MOSFET's
- Ni/Ge Schottky barriers for nanoelectronic applications
- Ge catalytic growth of Carbon Nanotubes
- Metal Oxide Tunnel Transistor

Grants

ADEPT - Advanced Devices by ElectroPlaTing, EPSRC £6,331,950, Jul 16 - Jul 21

Lead Niobate-based Tunable Dielectrics for Smart Microwave and Millimeter-wave Systems, EPSRC £849,965, Oct 16 - Apr 20

Selective Chemical Vapour Deposition for Production of Thermoelectric Micro-Generators for Energy Harvesting, STFC £363,110, Oct 16 - Oct 19

Metareflector: Next generation meta-materials based optical solar reflectors, EU Horizon 2020 £208,000, Jan 16-Dec 17

Spintronic device physics in Si/Ge Heterostructures, EPSRC £424,526, Mar 12 - Feb 16

Electrical and picosecond optical control of plasmonic nanoantenna hybrid devices, EPSRC £485,881, Jun 12 - May 15

Phase Change Memory Materials via Non-Aqueous Electrodeposition into Nano-structured Templates, EPSRC £916,818, Jan 11 - Jan 15

Semi-insulating Silicon substrates for high frequency integrated circuits, EPSRC £308,697, Jul 08 - Dec 11

Metal-Free Carbon Nanotube Growth for Nanoelectronics Applications, EPSRC £573,813, Oct 06 - Mar 10

Silicon-based nanodevices "Sinano", EU FP6 £150,000, Jan 04- Oct 07

Vertical Metal Oxide Tunnel Transistors, EPSRC £103,000, Mar 03 - Mar 06

Professional

Qualifications

1994 Masters, Physics, University of Groningen, the Netherlands
1998 Ph.D., Physics, University of Amsterdam, the Netherlands

Duties

Director of ECS Partners Ltd

Director of Nano-electronic characterisation facilities

Publications

2017

Fan, Junqing, Jiang, Liudi, Wang, Shuncai, Huang, Ruomeng, Morgan, Katrina, Zhong, Le and De Groot, Kees (2017) Amorphous SiC resistive memory with embedded Cu nanoparticles [in special issue: Micro/Nano Devices and Systems Edited by Bernhard Jakoby and Roman Beigelbeck] *Microelectronic Engineering*, 174, pp. 1-5. (doi:10.1016/j.mee.2016.12.005).

Huang, Ruomeng, Yan, Xingzhao, Ye, Sheng, Kashtiban, Reza J., Beanland, Richard, Morgan, Katrina A., Charlton, Martin D.B. and De Groot, C.H. (Kees) (2017) Compliance-free $ZrO_2/ZrO_{2-x}/ZrO_2$ resistive memory with controllable interfacial multistate switching behaviour *Nanoscale Research Letters*, 12, (384) (doi:10.1186/s11671-017-2155-0).

Riedel, Christoph A., Sun, Kai, Muskens, Otto L. and De Groot, Kees (2017) Nanoscale modeling of electro-plasmonic tunable devices for modulators and metasurfaces *Optics Express*, 25, (9), p. 10031. (doi:10.1364/OE.25.010031).

2016

Muskens, Otto L., Bergamini, Luca, Wang, Yudong, Gaskell, Jeffrey M., Zabala, Nerea, De Groot, C.H., Sheel, David W. and Aizpurua, Javier (2016) Antenna-assisted picosecond control of nanoscale phase-transition in vanadium dioxide *Light : Science & Applications*, pp. 1-25. (doi:10.1038/lsa.2016.173).

Fan, Junqing, Jiang, Liudi, Wang, Shuncai, Huang, Ruomeng, Morgan, Katrina, Zhong, Le and De Groot, Cornelis (2016) Dataset for Amorphous SiC resistive memory with embedded Cu nanoparticles University of Southampton doi:10.5258/SOTON/403082 [Dataset]

Muskens, Otto, Bergamini, Luca, WANG, YUDONG, Gaskell, Jeffrey M., Zabala, Nerea, De Groot, Cornelis, Sheel, David W. and Aizpurua, Javier (2016) Dataset for Antenna-assisted picosecond control of nanoscale phase-transition in vanadium dioxide University of Southampton doi:10.5258/SOTON/392922 [Dataset]

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Chatzikyriakou, Eleni and De Groot, Cornelis (2016) Dataset: RDF and TID simulation of PDSOI 45nm MOSFET University of Southampton doi:10.5258/SOTON/403024 [Dataset]

Hakim, M.M.A., De Groot, C.H., Hall, S. and Ashburn, Peter (2016) Drain current multiplication in thin pillar vertical MOSFETs due to depletion isolation and charge coupling *Journal of Computational Electronics*, 15, (3), pp. 839-849. (doi:10.1007/s10825-016-0853-y).

Huang, Ruomeng, Sun, Sun Kai, Kiang, Kian S., Morgan, Katrina and de Groot, C.H. (2016) Forming-free resistive switching of tunable ZnO films grown by atomic layer deposition *Microelectronic Engineering*, 161, pp. 7-12. (doi:10.1016/j.mee.2016.03.038).

Fan, Junqing, Jiang, Liudi, Zhong, Le, Gowers, Robert, Morgan, Katrina and De Groot, Cornelis (2016) Microstructure and electrical properties of co-sputtered Cu embedded amorphous SiC University of Southampton doi:10.5258/SOTON/388275 [Dataset]

Fan, Junqing, Jiang, Liudi, Zhong, Le, Gowers, Robert P., Morgan, Katrina and De Groot, C.H. (2016) Microstructure and electrical properties of co-sputtered Cu embedded amorphous SiC *Materials Letters*, 178, pp. 60-63. (doi:10.1016/j.matlet.2016.04.144).

Huang, Ruomeng, Benjamin, Sophie, Gurnani, Chitra, Wang, Yudong, Hector, Andrew, Levason, William, Reid, Gill and De Groot, Kees (2016) Nanoscale arrays of antimony telluride single crystals by selective chemical vapor deposition *Scientific Reports*, 6, (27593), pp. 1-10. (doi:10.1038/srep27593).

Morgan, Katrina, De Groot, Kees, Fan, Junqing, Gowers, Robert and Jiang, Liudi (2016) Switching mechanisms of Cu/SiC resistive memories with W and Au counter electrodes At *74th Device Research Conference, United States. 19 - 22 Jun 2016.* 2 pp.

Chatzikyriakou, Eleni, Potter, Kenneth, Redman-White, William and De Groot, Kees (2016) Three-dimensional Finite Elements method simulation of Total Ionizing Dose in 22 nm bulk nFinFETs *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, pp. 1-5. (doi:10.1016/j.nimb.2016.09.007).

Chatzikyriakou, Eleni, Morgan, Katrina, Ashburn, Peter, Redman-White, William and De Groot, Cornelis (2016) Total Ionizing Dose and random dopant fluctuation effects in 65-nm gate length partially depleted Silicon-on-Insulator nMOSFETs In *2015 IEEE 15th International Conference on Nanotechnology (IEEE-NANO).* IEEE., pp. 659-662. (doi:10.1109/NANO.2015.7388691).

Chatzikyriakou, Eleni, Redman-White, William and De Groot, Kees (2016) Total Ionizing Dose, Random Dopant Fluctuations and its combined effect in the 45 nm PDSOI node *Microelectronics Reliability*, pp. 1-9. (doi:10.1016/j.microrel.2016.11.007).

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Benjamin, Sophie L., de Groot, C.H., Hector, Andrew L., Huang, Ruomeng, Koukharenko, Elena, Levason, William and Reid, Gillian (2015) Chemical vapour deposition of antimony chalcogenides with positional and orientational control: precursor design and substrate selectivity *Journal of Materials Chemistry C*, 3, pp. 423-430. (doi:10.1039/C4TC02327G).

Gregory, Simon A., Wang, Yudong, de Groot, C.H. and Muskens, Otto L. (2015) Extreme Subwavelength Metal Oxide Direct and Complementary Metamaterials *ACS Photonics*, 2, (5), pp. 606-614. (doi:10.1021/acsphotonics.5b00089).

Bartlett, Philip N., Benjamin, Sophie L., de Groot, C.H. (Kees), Hector, Andrew L., Huang, Ruomeng, Jolleys, Andrew, Kissling, Gabriela, Levason, William, Pearce, Stuart J., Reid, Gillian and Wang, Yudong (2015) Non-aqueous electrodeposition of functional semiconducting metal chalcogenides: Ge2Sb2Te5phase change memory *Materials Horizons*, 2, (4), pp. 420-426. (doi:10.1039/C5MH00030K).

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Huang, Ruomeng, Kissling, Gabriela, Jolleys, Andrew, Bartlett, Philip, Hector, Andrew, Levason, William, Reid, Gillian and De Groot, Cornelis (2015) Phase-change memory properties of electrodeposited Ge-Sb-Te thin film *Nanoscale Research Letters*, 10, pp. 1-7. (doi:10.1186/s11671-015-1136-4).

Morgan, Katrina, Fan, Junqing, Huang, Ruomeng, Zhong, Le, Gowers, Robert, Jiang, Liudi and Groot, C.H. de (2015) Switching kinetics of SiC resistive memory for harsh environments *AIP Advances*, 5, (7), 077121-[7pp]. (doi:10.1063/1.4926674).

Black, Leo-Jay, Wiecha, Peter R., Wang, Yudong, de Groot, C. H., Paillard, Vincent, Girard, Christian, Muskens, Otto L. and Arbouet, Arnaud (2015) Tailoring second-harmonic generation in single L-shaped plasmonic nanoantennas from the capacitive to conductive coupling regime *ACS Photonics*, 2, (11), pp. 1592-1601. (doi:10.1021/acsphotonics.5b00358).

2014

Zhong, Le, Reed, P.A.S., Huang, Ruomeng, de Groot, C.H. and Jiang, Liudi (2014) Amorphous SiC based non-volatile resistive memories with ultrahigh ON/OFF ratios *Microelectronic Engineering*, 119, pp. 61-64. (doi:10.1016/j.mee.2014.02.004).

Huang, Ruomeng, Sun, Kai, Kiang, Kian Shen, Chen, Ruiqi, Wang, Yudong, Gholipour, Behrad, Hewak, D.W. and de Groot, C.H. (2014) Contact resistance measurement of Ge2Sb2Te5 phase change material to TiN electrode by spacer etched nanowire *Semiconductor Science and Technology*, 29, (9), p. 95003. (doi:10.1088/0268-1242/29/9/095003).

Benjamin, Sophie L., de Groot, C.H., Gurnani, Chitra, Hector, Andrew L., Huang, Ruomeng, Koukharenko, Elena, Levason, William and Reid, Gillian (2014) Controlling the nanostructure of bismuth telluride by selective chemical vapour deposition from a single source precursor *Journal of Materials Chemistry A*, 2, (14), pp. 4865-4869. (doi:10.1039/c4ta00341a).

Morgan, K., Huang, Ruomeng, Pearce, Stuart, Zhong, L., Jiang, Liudi and Groot, C. H. De (2014) Effect of stoichiometry of TiN electrode on the switching behavior of TiN/HfOx/TiN structures for resistive RAM At *2013 MRS Fall Meeting & Exhibit, United States. 01 - 06 Dec 2013.* (doi:10.1557/opl.2014.218).

Abb, Martina, Wang, Yudong, de Groot, C.H. and Muskens, Otto L. (2014) Hotspot-mediated ultrafast nonlinear control of multifrequency plasmonic nanoantennas *Nature Communications*, 5, (4869), pp. 1-8. (doi:10.1038/ncomms5869).

Zhong, Le, Jiang, Liudi, Huang, Ruomeng and Groot, C.H. de (2014) Nonpolar resistive switching in Cu/SiC/Au non-volatile resistive memory devices *Applied Physics Letters*, 104, (9), p. 93507. (doi:10.1063/1.4867198).

Black, Leo-Jay, Wang, Yudong, de Groot, C.H., Arbouet, Arnaud and Muskens, Otto L. (2014) Optimal polarization conversion in coupled dimer plasmonic nanoantennas for metasurfaces *ACS Nano*, 8, (6), pp. 6390-6399. (doi:10.1021/nn501889s).

Zhong, Le, Reed, P.A.S., Huang, Ruomeng, de Groot, C.H. and Jiang, Liudi (2014) Resistive switching of Cu/SiC/Au memory devices with a high ON/OFF ratio *Solid-State Electronics*, 94, pp. 98-102. (doi:10.1016/j.sse.2014.02.013).

Abb, Martina, Wang, Yudong, Papasimakis, Nikitas, de Groot, C.H. and Muskens, Otto L. (2014) Surface-enhanced infrared spectroscopy using metal oxide plasmonic antenna arrays *Nano Letters*, 14, (1), pp. 346-352. (doi:10.1021/nl404115g).

Wang, Yudong, Abb, Martina, Papasimakis, Nikitas, de Groot, C.H. and Muskens, Otto L. (2014) Surface-enhanced infrared spectroscopy using ultra-compact indium tin oxide (ITO) sensor arrays At *CLEO: Science and Innovations: Nano-, Micro-, and Waveguide-sensing (SM3E), United States. 09 - 13 Jun 2014.* , SM3E.7 -SM3E.9. (doi:10.1364/CLEO_SI.2014.SM3E.7).

Morgan, Katrina, de Groot, Kees and Huang, Ruomeng (2014) The effect of atomic layer deposition temperature on switching properties of HfOx resistive RAM devices At *IEEE International Symposium. 01 - 05 Jun 2014.*

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Morgan, Katrina, Huang, Ruomeng, Potter, Kenneth, Shaw, Chris, Redman-White, William and de Groot, Kees (2014) Total dose hardness of TiN/HfOx/TiN resistive random access memory *IEEE Transactions on Nuclear Science*, 61, (6), pp. 1-6. (doi:10.1109/TNS.2014.2365058).

Potter, Kenneth, Morgan, Katrina, Shaw, Chris, Ashburn, Peter, Redman-White, William and De Groot, Kees (2014) Total ionizing dose response of fluorine implanted silicon-on-insulator buried oxide *Microelectronics Reliability*, 54, (9-10), pp. 2339-2343. (doi:10.1016/j.microrel.2014.07.018).

Wang, Yudong, Abb, Martina, Boden, Stuart A., Aizpurua, Javier, De Groot, C.H. and Muskens, Otto L. (2014) Ultrafine control of partially loaded single plasmonic nanoantennas fabricated using e-beam lithography and helium ion beam milling At *CLEO: QELS Fundamental Science: Photonic Crystals and Complex Plasmonic Nanostructures (FF1K), United States. 08 - 13 Jun 2014.* , FF1K.1-FF1K.2. (doi:10.1364/CLEO_QELS.2014.FF1K.1).

2013

Huang, Ruomeng, Sun, Kai, Kiang, Kian Shen, Chen, Ruiqi, Wang, Yudong, Gholipour, Behrad, Hewak, Daniel W., Hector, Andrew L., Reid, Gillian and de Groot, C.H. (2013) A novel top-down fabrication process for Ge2Sb2Te5 phase change material nanowires At *13th Non-Volatile Memory Technology Symposium (NVMTS), United States. 12 - 14 Aug 2013.* , pp. 2-5.

Benjamin, Sophie, de Groot, C.H., Gurnani, Chitra, Hector, Andrew L., Huang, Ruomeng, Ignatyev, Konstantin, Levason, William, Pearce, Stuart, Thomas, Fiona and Reid, Gillian (2013) Area selective growth of titanium diselenide thin films into micropatterned substrates by low-pressure chemical vapor deposition *Chemistry of Materials*, 25, (23), pp. 4719-4724. (doi:10.1021/cm402422e).

Wang, Yudong, Abb, Martina, Boden, Stuart, de Groot, C.H. and Muskens, Otto L. (2013) Controlled fabrication of plasmonic nanogaps using electron beam lithography and helium-ion beam milling At *39th International Conference on Micro and Nano Engineering, United Kingdom. 16 - 19 Sep 2013.*

Huang, R., Chen, R., Gholipour, B., Kiang, K.S., Sun, K., Wang, Y. and de Groot, C.H. (2013) Determination of specific contact resistance of Ge2Sb2Te5 phase change materials by spacer etched nanowires At *13th Non-Volatile Memory Technology Symposium, United States. 12 - 14 Aug 2013.*

Dong, L., de Groot, C.H., Usgaocar, A. and Chavagnac, V. (2013) Effect of interfacial PdNi concentration on time response of Si-based electrodeposited hydrogen sensors At *Transducers 2013 & Eurosensors XXVII: The 17th International Conference on Solid-State Sensors, Actuators, and Microsystems, Spain. 16 - 20 Jun 2013.* 4 pp.

Uchino, T., Shimpo, F., Kawashima, T., Ayre, G.N., Smith, D.C., de Groot, C.H. and Ashburn, P. (2013) Electrical transport properties of isolated carbon nanotube/Si heterojunction Schottky diodes *Applied Physics Letters*, 103, (19), pp. 1-3. (doi:10.1063/1.4829155).

George, Kathryn, Groot, C. H. De, Gurnani, Chitra, Hector, Andrew L., Huang, Ruomeng, Jura, M., Levason, William and Reid, Gillian (2013) Low pressure chemical vapour deposition of crystalline Ga2Te3 and Ga2Se3 thin films from single source precursors using telluroether and selenoether complexes *Physics Procedia*, 46, pp. 142-148. (doi:10.1016/j.phpro.2013.07.056).

Bartlett, Philip N., Cook, David A., de Groot, C.H., Hector, Andrew L., Huang, Ruomeng, Jolleys, Andrew, Kissling, Gabriela P., Levason, William, Pearce, Stuart and Reid, Gillian (2013) Non-aqueous electrodeposition of metals and metalloids from halometallate salts *RSC Advances*, 3, (36), pp. 15645-15654. (doi:10.1039/c3ra40739j).

Huang, Ruomeng, Bartlett, Philip N., Benjamin, Sophie L., Gurnani, Chitra, Hector, Andrew L., Jolleys, Andrew, Kissling, G., Levason, William, Pearce, Stuart, Reid, Gillian and de Groot, C.H. (2013) Selective deposition of phase change materials by chemical vapor deposition and electrodeposition At *European Phase Change and Ovonics Symposium, Germany. 08 - 10 Sep 2013.*

George, Kathryn, de Groot, Cornelis H., Gurnani, Chitra, Hector, Andrew L., Huang, Ruomeng, Jura, Marek, Levason, William, Reid, Gillian and Huang, R (2013) Telluroether and Selenoether complexes as single source reagents for low pressure chemical vapor deposition of crystalline Ga2Te3 and Ga2Se3 thin films *Chemistry of Materials*, 25, (9), pp. 1829-1836. (doi:10.1021/cm400382j).

Wang, Yudong, Abb, Martina, Boden, Stuart A., Aizpurua, Javier, de Groot, C.H. and Muskens, Otto L. (2013) Ultrafast Nonlinear control of progressively loaded, single plasmonic nanoantennas fabricated using helium ion milling *Nano Letters*, 13, (11), pp. 5647-5653. (doi:10.1021/nl403316z). (PMID:24127754).

2012

Dong, Longtao, de Groot, C.H., Usgaocar, A. and Chavagnac, V. (2012) Electro-deposited PdNi-Si Schottky barrier hydrogen sensors with improved time response At *Eurosensors 2012: The 26th European Conference on Solid-State Transducers, Poland. 09 - 12 Sep 2012.* , 37 - 40. (doi:10.1016/j.proeng.2012.09.078).

Wang, Yudong, Boden, Stuart, Bagnall, Darren, Rutt, H.N. and de Groot, C.H. (2012) Helium ion beam milling and electron beam lithography to create sub-20nm sized domain wall magnetoresistance spin-valve At *38th International Micro & Nano Engineering Conference, France. 16 - 20 Sep 2012.*

Wang, Yudong, Boden, S.A., Bagnall, D.M., Rutt, H.N. and de Groot, C.H. (2012) Helium ion beam milling to create a nano-structured domain wall magnetoresistance spin valve *Nanotechnology*, 23, pp. 395302-1. (doi:10.1088/0957-4484/23/39/395302).

de Groot, C.H., Gurnani, Chitra, Hector, Andrew L., Huang, Ruomeng, Jura, Marek, Levason, William and Reid, Gillian (2012) Highly selective chemical vapor deposition of tin diselenide thin films onto patterned substrates via single source diselenoether precursors *Chemistry of Materials*, 22, (24), pp. 4442-4449. (doi:10.1021/cm302864x).

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Hakim, M.M.A., Abuelgasim, A., Tan, L., de Groot, C.H., Redman-White, W., Hall, S. and Ashburn, P. (2011) Improved drive current in RF vertical MOSFETS using hydrogen anneal *IEEE Electron Device Letters*, 32, (3), pp. 279-281. (doi:10.1109/LED.2010.2101042).

Wang, Yudong, de Groot, C.H., Fangohr, H. and Gonzalez Diaz, C. (2011) Magneto-resistance in a lithography defined single constrained domain wall spin valve At *IEEE Asia International Magnetics Conference, Taiwan, Province of China. 25 - 29 Apr 2011.*

Uchino, T., Ayre, G.N., Smith, D.C., Hutchison, J.L., de Groot, C.H. and Ashburn, P. (2011) Metal catalyst-free growth of carbon nanotubes and their application in field effect transitors *Electrochemical Society Letters*, 156, (8), k144-k148.

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Ayre, G.N., Uchino, T., Mazumder, B., Hector, A.L., Hutchison, J.L., Smith, D.C., Ashburn, P. and de Groot, C.H. (2011) On the mechanism of carbon nanotube formation: the role of the catalyst *Journal of Physics: Condensed Matter*, 23, (39), p. 394201. (doi:10.1088/0953-8984/23/39/394201). (PMID:21921315).

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