CURRICULUM VITAE

Prof Rahul Raveendran Nair

Personal information

Name**:** Rahul Raveendran Nair

Date of birth: 17 May 1983

Web site: http://rrnair.weebly.com/

Education

- Feb. 2007 to Dec. 2010, **Doctoral Degree (PhD)** in Condensed Matter Physics, The University of Manchester, Manchester, United Kingdom

Thesis: *"Atomic structure and properties of graphene and novel-graphene derivatives"*, under the supervision of Prof. Andre Geim

- Jun. 2003 to Mar. 2005, **MSc Physics**, A Grade (8.3/10), Mahatma Gandhi University, Kerala, India

Awards

- 2016, **Highly Cited Researcher,** Thomson Reuters (Highly Cited Papers are defined as those that rank in the top 1% by citations for field and publication year in the Web of Science)
- 2015, **The Moseley medal and prize**, Institute of Physics (IOP)
- Oct. 2014 to Sep. 2019, **Royal Society University Research Fellowship**, The Royal Society, United Kingdom
- 2014, **IUPAP young scientist prize**, The International Union of Pure and Applied Physics
- Sep. 2012 to Sep. 2014, **Leverhulme Fellowship**, The Leverhulme Trust, United Kingdom
- Feb. 2007 to Dec. 2010, **UK-India Education and Research Initiative Scholarship**, British Council, United Kingdom
- Jun. 2003 to Mar. 2005, **Merit Scholarship**, Mahatma Gandhi University, Kerala, India
- Jun. 2003 to Mar. 2005, **Merit Scholarship**, Kerala State Government, India

Appointments

- July 2016 to present – **Professor of Materials Physics**, National Graphene Institute and School of Chemical Engineering and Analytical Science, The University of Manchester, UK
- Sep. 2015 to June 2016 – **Reader in Physics/Royal Society University Research Fellow**, Condensed Matter Physics Group, School of Physics and Astronomy, The University of Manchester, UK
- Oct. 2014 to Aug.2015, **Royal Society University Research Fellow**, Condensed Matter Physics Group, School of Physics and Astronomy, The University of Manchester, UK
- Sept. 2012 to Sept.2014, **Leverhulme Fellow**, Condensed Matter Physics Group, School of Physics and Astronomy, The University of Manchester, UK
- Mar. 2011 to Aug. 2012, **Research Associate**, Condensed Matter Physics Group, School of Physics and Astronomy, The University of Manchester, UK
- Nov. 2005 to Jan. 2007, **Research Assistant** in the Department of Physics, Indian Institute of Science, Bangalore, India

SELECTED RESEARCH HIGHLIGHTS

I am currently a Professor of Materials Physics and hold a prestigious Royal Society Fellowship. The main scope of his research is the novel synthesis and construction of application-oriented devices based on two-dimensional (2D) crystals and their modifications. To a large extent, I am actively pursuing this modification

of native 2D crystals and synthesized novel 2D materials, in order to explore new physical phenomena. A few selected research highlights are listed below.

Graphene Optics: My work demonstrated that absorption of visible light by graphene is governed by fundamental physical constants: graphene absorbs ≈2.3% of light, which corresponds to just π times the fine structure constant (Nair *et al*. ***Science*** 320, 1308, 2008).

Graphene Chemistry: I successfully synthesised and studied different physical and chemical properties of new graphene-based chemical derivatives, mainly hydrogenated (*graphane*, Elias & Nair *et al.* ***Science***, 323, 610, 2009) and fluorinated graphene (*fluorographene*, Nair *et al.* ***Small***, 6, 2877, 2010).

Atomic Structure of Graphene: I have contributed substantially to the investigation of the structural properties of free-standing graphene by using high resolution transmission electron microscopy and electron diffraction techniques. We have managed to obtain the first direct (i.e. real-space) visualisation of the atomic structure of graphene (Gass *et al.* ***Nature Nanotechnology***, 3, 676, 2008).

Magnetic properties: In its pristine state, graphene exhibits no sign of conventional magnetism. Yet, we found that when introducing defects in the graphene lattice (through ion bombardment or by chemical functionalisation with other nonmagnetic atoms like fluorine), graphene became magnetic (Nair *et al*. ***Nature Phys.***, 8, 199, 2012). We additionally demonstrated that controlled molecular doping of graphene leads to this defect-induced magnetism becoming tunable (Nair *et al*. ***Nature Commun.*** 4, 2010, 2013).

Superpermeable graphene membranes: Another exciting discovery in my research was the observation of superpermeable water flow through helium leak-tight graphene based membranes. We have found that membranes made from graphene oxide, a chemical derivative of graphene, are impermeable to all gases and liquids. However, water permeates through them as quickly as if the membranes were not there at all. This work also attracted significant attention by media; including articles in scientific magazines (Nair *et al.* ***Science***, 335, 442, 2012). I continued this controlled and scalable fabrication of graphene based membranes and as of now, it led to securing more than £7M research grant with the collaboration with large industrial companies (DSTL, Lockheed Martin, Bluestone Global Tech., amongst others). These collaborative efforts lead to another ground breaking research on graphene oxide membranes. My work demonstrates that vacuum tight graphene oxide membranes act as a molecular sieve, blocking all solutes with hydrated radii larger than 4.5 angstroms if immersed in water (Joshi *et al.* ***Science,*** 343, 752, 2014).

Graphene based barrier films: Our research demonstrates that it is possible to tightly close the superpermeable nanocapillaries in the graphene oxide membranes by using simple chemical treatments, which makes graphene films even stronger mechanically as well as completely impermeable to everything: gases, liquids or strong chemicals. For example, we demonstrate that glassware or copper plates covered with graphene paint can be used as containers for strongly corrosive acids (Su et al. ***Nature Commun.***5, 4843, 2014).

Superconductivity in Graphene: Our research shows that graphene laminates doped with calcium exhibit robust superconductivity with a transition temperature governed by the electron transfer from the metal to graphene and by the Ca-layer confinement (J. Chapman *et al.* ***Scientific Reports*** **6**, 23254, 2016).

Van der Waals pressure: Molecules trapped between the layers of two-dimensional materials are thought to experience high pressure. Our research report measurements of this interfacial pressure by capturing pressure-sensitive molecules and studying their structural changes, and show that it can also induce novel chemical reaction (Vasu *et al.* ***Nature Commun.*** **7,** 12168, 2016).

Tunable ion sieving: Our latest research demonstrates that ion permeation and selectivity of graphene oxide membranes with sub-nm channels dramatically alters with the change in interlayer distance due to dehydration effects whereas permeation of water molecules remains largely unaffected. Our work shows a possible route to production of GO membranes with controllable interlayer spacing for desalination applications. (J. Abraham *et al.* ***Nature Nanotechnology*** 2017)

FULL LIST OF PUBLICATIONS

Published over 45 highly cited peer-refereed research articles, including four *Science*, two *Nature*, one *Nature Physics*, two *Nature Nanotechnology*, and *six Nature Communications* during the last nine years.

Google scholar id : http://scholar.google.co.uk/citations?user=tuQSdiUAAAAJ&hl=en

Total citations: >16500 times. h-index 31. Current citation rate: > 1500 per annum

1. H. Ghorbanfekr-Kalashami, K. S. Vasu, **R. R. Nair**, Francois M. Peeters & M. Neek-Amal "Dependence of the shape of graphene nanobubbles on trapped substance" ***Nature Communications*** **8**, 15844 (2017)
2. J. Abraham, K. S. Vasu, C. D. Williams, K. Gopinadhan, Y. Su, C. T. Cherian, J. Dix, E. Prestat, S. J. Haigh, I. V. Grigorieva, P. Carbone, A. K. Geim, **R. R. Nair** *"Tuneable Sieving of Ions Using Graphene Oxide Membranes*" **Nature Nanotechnology 12**, 546–550 (2017).
3. Stuart M. Holmes, Prabhuraj Balakrishnan, Vasu Kalangi, Xiang Zhang, Marcelo Lozada-Hidalgo, Pulickel M. Ajayan & **Rahul R. Nair** "*2D Crystals Significantly Enhance the Performance of a Working Fuel Cell*" **Advanced Energy Materials**, 1601216 (2016).
4. K. S. Vasu, E. Prestat, J. Abraham, J. Dix, R. J. Kashtiban, J. Beheshtian, J. Sloan, P. Carbone, M. Neek-Amal, S. J. Haigh, A. K. Geim & **R. R. Nair** *"Van der Waals pressure and its effect on trapped interlayer molecules"* **Nature Communications 7**, 12168 (2016).
5. J. Chapman, Y. Su, C. A Howard, D. Kundys, A. N. Grigorenko, F. Guinea, A. K. Geim, I. V Grigorieva & **R. R . Nair "***Superconductivity in Ca-doped graphene"* **Scientific Reports 6,** 23254 (2016).
6. S. Kar, Y. Su, **R. R Nair** & A. K Sood *"Probing Photoexcited Carriers in a Few-Layer MoS2 Laminate by Time-Resolved Optical Pump–Terahertz Probe Spectroscopy"* **ACS Nano 9**, 12004-12010 (2015).
7. G. Algara-Siller, O. Lehtinen, F. C Wang, **R. R. Nair**, U. Kaiser, H. A Wu, I. V Grigorieva & A. K Geim "*Square ice in graphene nanocapillaries*" **Nature 519,** 443-445 (2015).
8. S. Hu, M. Lozada-Hidalgo, F. C Wang, A. Mishchenko, F. Schedin, **R. R. Nair**, E. W Hill, D. W Boukhvalov, M. I Katsnelson, R. A. W Dryfe, I.V Grigorieva, H. A Wu & A. K Geim "*Proton transport through one atom thick crystals*" **Nature 516,** 227-230 (2014).
9. S. Kumar, **R. R. Nair**, P. B Pillai, S. N Gupta, M. A Iyengar & A. K Sood "*Graphene Oxide-MnFe2O4 Magnetic Nanohybrids for Efficient Removal of Lead and Arsenic from Water*." ***ACS applied materials & interfaces*** **6**, 17426-17436 (2014).
10. Reza J Kashtiban, M Adam Dyson, **Rahul R Nair**, Recep Zan, Swee L Wong, Quentin Ramasse, Andre K Geim, Ursel Bangert & Jeremy Sloan "*Atomically resolved imaging of highly ordered alternating fluorinated graphene*" ***Nature Communications*** **5**, 4902 (2014).
11. Y. Su, V. G. Kravets, S. L. Wong, J. Waters, A. K. Geim & **R. R. Nair** "*Impermeable Barrier Films and Protective Coatings Based on Reduced Graphene Oxide" **Nature Communications*** **5**, 4843 (2014).
12. Panit Chantharasupawong, Cory W Christenson, Reji Philip, Lei Zhai, Jeffrey Winiarz, Michiharu Yamamoto, Laurene Tetard, **Rahul R Nair** & Jayan Thomas "*Photorefractive performances of a graphene-doped PATPD/7-DCST/ECZ composite*" ***Journal of Materials Chemistry C,*** **2**, 7639 (2014).
13. Ossi Lehtinen, I-Ling Tsai, Rashid Jalil, **Rahul R Nair**, Juhani Keinonen, Ute Kaiser & Irina V Grigorieva *"Non-invasive transmission electron microscopy of vacancy defects in graphene produced by ion irradiation" **Nanoscale*** **6, 6569** (2014).
14. R. K. Joshi, P. Carbone, F. C. Wang, V. G. Kravets, Y. Su, I. V. Grigorieva, H. A. Wu, A. K. Geim & **R. R. Nair "***Precise and ultrafast molecular sieving through graphene oxide membranes" **Science,*** **343,** 752 (2014).
15. **R. R. Nair**, I-L Tsai, M. Sepioni, O. Lehtinen, J. Keinonen, A.V. Krasheninnikov, A. H. Castro Neto, M. I. Katsnelson, A. K. Geim & I. V. Grigorieva *"Dual origin of defect magnetism in graphene and its reversible switching by molecular doping" **Nature Communications*** **4**, 2010 (2013).
16. D. Brida, A. Tomadin, C. Manzoni, Y. J. Kim, A. Lombardo, S. Milana, **R. R. Nair**, K. S. Novoselov, A. C. Ferrari, G. Cerullo & M. Polini *"Ultrafast collinear scattering and carrier multiplication in graphene" **Nature Communications*** **4**, 1987 (2013).
17. H. Ali-Boucetta, D. Bitounis, **R. R. Nair** A. Servant, J. Van den Bossche & K. Kostarelos "*Purified graphene oxide dispersions lack in vitro cytotoxicity and in vivo pathogenicity" **Adv. Healthcare Mater.*** **2**, 512 (2013).

18. P. Kossacki, C. Faugeras, M. Kühne, M. Orlita, A. Mahmood, E. Dujardin, **R. R. Nair**, A. K. Geim, & M. Potemski *"Circular dichorism of magnetophonon resonance in doped graphene"* ***Phys. Rev. B*** **86**, 205431 (2012).

19. M. Sepioni, **R. R. Nair**, I.-Ling Tsai, A. K. Geim & I. V. Grigorieva *"Reply to the comment by D. Spemann et al."* ***Europhys. Lett***. **98**, 57007 (2012).

20. M. Sepioni, **R. R. Nair**, I-Ling Tsai, A. K Geim & I. V Grigorieva, "*Revealing common artifacts due to ferromagnetic inclusions in highly oriented pyrolytic graphite*" ***Europhys. Lett***. **97**, 47001 (2012).

21. **R. R. Nair**, M. Sepioni, I-Ling Tsai, O. Lehtinen, J. Keinonen, A. V. Krasheninnikov, T. Thomson, A. K. Geim & I. V. Grigorieva, "*Spin-half paramagnetism in graphene induced by point defects*" ***Nature Phys.*** **8**, 199 (2012).

22. **R. R. Nair**, H. A. Wu, P. N. Jayaram, I. V. Grigorieva & A. K. Geim, "*Unimpeded permeation of water through helium-leak–tight graphene-based membranes*" ***Science*** **335**, 442 (2012).

23. C. T. Pan, **R. R. Nair**, U. Bangert, Q. Ramasse, R. Jalil, R. Zan, C. R. Seabourne & A. J. Scott, "*Nanoscale electron diffraction and plasmon spectroscopy of single- and few-layer boron nitride*" ***Phys. Rev. B*** **85**, 045440 (2012).

24. Jakob Zabel, **Rahul R. Nair**, Anna Ott, Thanasis Georgiou, Andre K. Geim, Kostya S. Novoselov & Cinzia Casiraghi, "*Raman spectroscopy of graphene and bilayer under biaxial strain: bubbles and balloons*" ***NanoLett.*** **12**, 617 (2012).

25. A. Luican, Guohong Li, A. Reina, J. Kong, **R. R. Nair**, K. S. Novoselov, A. K. Geim & E.Y. Andrei, "*Single layer behavior and its breakdown in twisted graphene layers*" ***Phys. Rev. Lett.*** **106**, 126802 (2011).

26. F. Carbone, G. Aubock, A. Cannizzo, F. Van Mourik, **R.R. Nair**, A.K. Geim, K.S. Novoselov & M. Chergui, "*Femtosecond carrier dynamics in bulk graphite and graphene paper*" ***Chem. Phys.Lett.*** **504**, 37 (2011).

27. Roman V. Gorbachev, Ibtsam Riaz, **Rahul R. Nair**, Rashid Jalil, Liam Britnell, Branson D. Belle, Ernie W. Hill, Kostya S. Novoselov, Kenji Watanabe, Takashi Taniguchi, Andre K. Geim & Peter Blake, "*Hunting for monolater boron nitride: optical and raman signatures*" ***Small*** **7**, 465 (2011).

28. U. Bangert, C. T. Pan, **R. R. Nair** & M. H. Gass, "*Structure of hydrogen-dosed graphene deduced from low electron energy loss characteristics and density functional calculations*" ***Appl. Phys. Lett.*** **97**, 253118 (2010).

29. **R. R. Nair**, W. Ren, R. Jalil, I. Riaz, V. G. Kravets, L. Britnell, P. Blake, F. Schedin, A. S. Mayorov, S. Yuan, M. I. Katsnelson, H.-M. Cheng, W. Strupinski, L. G. Bulusheva, A. V. Okotrub, I. V. Grigorieva, A. N. Grigorenko, K. S. Novoselov & A. K. Geim, ***"****Fluorographene: A two-dimensional counterpart of Teflon*" ***Small*** **6**, 2877 (2010).

30. M. Sepioni, **R. R. Nair**, S. Rablen, J. Narayanan, F. Tuna, R. Winpenny, A. K. Geim & I. V. Grigorieva, "*Limits on intrinsic magnetism in graphene*" ***Phys. Rev. Lett.*** **105**, 207205 (2010).

31. Z. H. Ni, L. A. Ponomarenko, **R. R. Nair**, R. Yang, S. Anissimova, I. V. Grigorieva, F. Schedin, P. Blake, Z. X. Shen, E. H. Hill, K. S. Novoselov & A. K. Geim "*On resonant scatterers as a factor limiting carrier mobility in graphene*" ***Nano Lett.*** **10**, 3868 (2010).

32. **R. R. Nair**, P. Blake, J. R. Blake, R. Zan, S. Anissimova, U. Bangert, A. P. Golovanov, S. V. Morozov, A. K. Geim & K. S. Novoselov "*Graphene as a transparent conductive support for studying objects by transmission electron microscopy*" ***Appl. Phy. Lett.*** **97**, 153102 (2010).

33. V. G. Kravets, A. N. Grigorenko, **R. R. Nair**, P. Blake, S. Anissimova, K. S. Novoselov & A. K. Geim "*Spectroscopic ellipsometry of graphene and an exciton-shifted van Hove peak in absorption*" ***Phys. Rev. B*** **81**, 155413 (2010).

34. C. Faugeras, B. Faugeras, M. Orlita, M. Potemski, **R. R. Nair** & A. K. Geim "*Thermal conductivity of graphene in corbino membrane geometry*" ***ACS Nano*** **4**, 1889 (2010).

35. T. Gokus, **R. R. Nair**, A. Bonetti, M. Bohmler, A. Lombardo, K. S. Novoselov, A. K. Geim, A. C. Ferrari & A. Hartschuh "*Making graphene luminescent by oxygen plasma treatment*" ***ACS Nano*** **3**, 3963 (2009).

36. A. J Pollard, **R. R. Nair**, S. N. Sabki, C. R. Staddon, L. M. A. Perdigao, C. H. Hsu, J. M. Garfitt, S. Gangopadhyay, H. F. Gleeson, A. K. Geim & P. H. Beton "*Formation of monolayer graphene by annealing sacrificial nickel thin films*" ***J. Phys. Chem. C*** **113,** 16565 (2009).

37. U. Bangert, M. H. Gass, A. L. Bleloch, **R. R. Nair** & J. Eccles "*Nanotopography of graphene*" ***Physica Status Solidi A – Applications and Materials Science*** **206,** 2115 (2009).

38. P. Blake, R. Yang, S. V. Morozov, F. Schedin, L. A. Ponomarenko, A. A. Zhukov, **R. R. Nair**, I. V. Grigorieva, K. S. Novoselov & A. K. Geim "*Influence of metal contacts and charge inhomogeneity on transport properties of graphene near the neutrality point*" ***Solid State Communications*** **149**, 1068 (2009).

39. U. Bangert, M. H. Gass, A. L. Bleloch, **R. R. Nair** & A. K. Geim "*Manifestation of ripples in free-standing graphene in lattice images obtained in an aberration-corrected scanning transmission electron microscope*" ***Physica Status Solidi A – Applications and Materials Science*** **206,** 1117 (2009).

40. T. M. G. Mohiuddin, A. Lombardo, **R. R. Nair**, A. Bonetti, G. Savini, R. Jalil, N. Bonini, D. M. Basko, C. Galiotis, N. Marzari, K. S. Novoselov, A. K. Geim & A. C. Ferrari "*Uniaxial strain in graphene by Raman spectroscopy: G peak splitting, Gruneisen parameters and sample orientation*" ***Phys. Rev. B*** **79**, 205433 (2009).

41. 39. D. C. Elias*, **R. R. Nair***, T. M. G. Mohiuddin, S. V. Morozov, P. Blake, M. P. Halsall, A. C. Ferrari, D. W. Boukhvalov, M. I. Katsnelson, A. K. Geim & K. S. Novoselov *"Control of graphene's properties by reversible hydrogenation"* **Science 323**, 610 (2009). (* Both authors have equal contribution

42. **Rahul Nair**, B. Premlal, Anindya Das & A. K. Sood "*Enhanced field emission from carbon nanotube-conducting polymer composites with low loading*" ***Solid State Communications*** **149**, 150 (2009).

43. Mhairi H. Gass, Ursel Bangert, Andrew L. Bleloch, Peng Wang, **Rahul R. Nair** & A. K. Geim "*Free standing graphene at atomic resolution*" ***Nature Nanotechnology*** **3**, 676 (2008).

44. U. Bangert, T. Eberlein, **R. R. Nair**, R. Jones, M. Gass, A. L. Bleloch, K. S. Novoselov, A. Geim & P. R. Briddon "*STEM plasmon spectroscopy of free standing graphene*" ***Physica Status Solidi A – Applications and Materials Science*** **205,** 2265 (2008).

45. T. J. Booth, P. Blake, **R. R. Nair**, D. Jiang, E. W. Hill, U. Bangert, A. Bleloch, M. Gass, K. S. Novoselov, M. I. Katsnelson & A. K. Geim "*Macroscopic graphene membranes and their extraordinary stiffness*" ***Nano Lett.*** **8**, 2442 (2008).

46. T. Eberlein, U. Bangert, **R. R. Nair**, R. Jones, M. Gass, A. L. Bleloch, K. S. Novoselov, A. Geim & P. R. Briddon "*Plasmon spectroscopy of free-standing graphene films*" ***Phys. Rev. B*** **77**, 233406 (2008).

47. Peter Blake, Paul D. Brimicombe, **Rahul R. Nair**, Tim J. Booth, Da Jiang, Fred Schedin, Leonid A. Ponomarenko, Sergey V. Morozov, Helen F. Gleeson, Ernie W. Hill, Andre K. Geim & Kostya S. Novoselov "*Graphene-based liquid crystal device*" ***Nano Lett.*** **8,** 1704 (2008).

48. **R. R. Nair**, P. Blake, A. N. Grigorennko, K. S. Novoselov, T. J. Booth, T. Stauber, N. M. R. Peres & A. K. Geim "*Fine structure constant defines visual transparency of graphene*" ***Science*** **320**, 1308 (2008).