Curriculum Vitae: Taron MAKARYAN, Ph.D.

My current project is focused on the investigation of carbon-based and 2D metal-carbide materials for energy storage applications and electronic devices. Previous research experience includes carbon nanotubes and graphene synthesis/characterization, and plasmonics of noble metal nanoparticles.

Post Doctoral Researcher

3141 Chestnut Street
Philadelphia, PA 19104
Emails: taron.makaryan@drexel.edu
tmakaryan@gmail.com
Tel: +1-215-495-8781

Education

- **Radiophysics Department, Yerevan State University (YSU)** Yerevan, Armenia
  ***Ph.D.** in Physics* *2008 – 2012*

  Thesis: "Surface Plasmons in Metal Nanosphere and Nanorod Pairs"
  - Supervisors: Prof. Hayk Minassian and Prof. Armen Melikyan
  - Numerical study of surface plasmons (SP) of coupled metal nanospheres and nanorods, for applications in sensors and light enhancement. Analytical study of a metal nanoparticle near the dielectric interface.

  Numerical simulations tools:

  DDSCAT 7.0, which is based on Discrete Dipole Approximation (DDA) method, was applied to verify analytical results and limits of applicability of analytical methods. Validity of an analytical method, which was developed earlier by H.Minassian and A.Melikyan for calculating the SP of single metal nanorods, is also verified by using DDSCAT.

  COMSOL 3.5a, which is based on finite elements (FE) method, wass used to describe the scattered electric field distribution and the enhancement from coupled spheres and rods depending on particle separation.

- **Institute of Experimental Physics, University of Ulm** Ulm, Germany
  *Master of Science (**M.Sc.**) in Advanced Materials* *2008 – 2010*

  Thesis: "Investigation of the Optical Near-Fields of Metal Nanoparticles and Dimers"
  - Supervisors: Prof. Othmar Marti and Prof. Paul Ziemann
  - Optical near-fields of as-produced samples (hexagonal arrays of triangular metal nanoparticles on glass substrate) are investigated experimentally. Far-field optical and atomic force microscopy methods are also applied for having a better view of optical properties and the surface topography of nanoparticles. Applications of synthesized samples: sensorics, Raman spectroscopy, solar cell efficiency improvement.

  Sample synthesis:

  Ordered Hexagonal arrays of triangular metal nanoparticles are produced by a **Nanosphere soft litho-graphy** method using 0.5 to 3 μm polystyrene spheres and thermal metal deposition onto the particles' surface in an ultra-high vacuum chamber.

  Experimental characterization tools:

  Scanning near-optical microscopy working with embedded atomic force microscopy in contact-mode for simultaneously observing particles optical coupling and topography,

  Surface enhanced Raman spectroscopy for measuring Raman enhancement of triangular metal nanoparticles and differential stain of various dyes,

  Angle-resolved spectroscopy in Kretschmann configuration for observing surface plasmon-polaritons of various nanoparticle arrays and diffraction gratings,

  Confocal optical microscopy (reflection, scattering) for describing triangular metal nanoparticles

reflectance and light scattering depending on incident light polarization,

Atomic force microscopy in tapping-mode for characterizing surface roughness, for measuring the deposited height and the surface topography of nanoparticles.

- **Radiophysics Depratment, Yerevan State University (YSU)** Yerevan, Armenia
  *Master of Science (**M.Sc.**) in Radiophysics and Electronics (Grades: 100%)* *2006 –2008*

  *Thesis: "*Calculation of Plasmon Frequencies of Coupled Metallic Nanospheres"
  - Supervisors: Prof. Hayk Minassian and Prof. Armen Melikyan
  - Semi-Analytical Method is developed ("*Eliminated Quadrupole Moment Approximation*") for calculating surface plasmon (SP) frequencies of coupled dielectric shell-covered metal nanospheres. Analytic equations are obtained for the dependence of the SP on the inter-particle distance and size of the particles, dielectric functions of spheres and surrounding medium.

- **Radiophysics Depratment, Yerevan State University (YSU)** Yerevan, Armenia
  ***Bachelor** in Radiophysics and Electronics* *2002 – 2006*

  Diploma with Distinction

Work/Internship Experience

- **Drexel University** Philadepelphia, PA, USA
  ***Post-doctoral Researcher** in Drexel Institute of Nanomaterials (Head Prof. Yury Gogotsi)* *Apr. 2015 – ongoing*

  - Characterization and analysis of carbon-based materials by thermogravimetry, porosimetry, high-temperature gas treatment, electrochemistr in situ Raman spectroelectrochemistry, infrared spectroscopy, for energy storage applications.
  - Nanoindentation of carbon-based materials
  - Electronic and energy saving device fabrication and characterization
  - Students training of various instruments (Raman, BET, FTIR) and other methods (e.g. gas treatment).
  - Helping organize seminars/events: "Carbons for Electrochemistry' section in CARBON-2016 Conference

- **Korea Advanced Institute of Science and Technology** Daejeon, Rep. Korea
  Research Fellow *in National Nanofabrication Laboratory* *Aug. – Oct. 2016*

  - Designed and conducted fabrication of electronic devices based on 2D single nanoflake materials by Silicon Semiconductors Technology
  - Member of team that launched international research collaboration between Drexel University and National Nanofabrication Center (NNFC) at KAIST

- **Institute of Radiophysics and Electronics** Ashtarak, Armenia
  ***Researcher** in Lab. of Solid-State Physics* *Feb. 2014 – Apr. 2015*

  - Growth of CdS nanowires for photo-luminescence applications by catalytic chemical vapor deposition (CVD) method. Design and assembly of experimental setup and synthesis
  - Perform RF electronic measurements on 2D CNT networks surfaces.
  - Design shielded/filtered system for low-noise electronic measurements. Characterize intrinsic fluctuations in the sample up to MHz.
  - Students training on furnaces, device preparation.

- **Engineering Department, University of Cambridge** Cambridge, United Kingdom
  Post-doctoral Researcher to Prof. John Robertson *Jul. 2012 – Dec. 2014*

  - Catalytic growth of **Carbon Nanotube (CNT) Forests** by low- and atmospheric-pressure CVD for VIA interconnect and other applications
  - Growth of carbon nanotube forests by exploiting supporting layers for the catalyst nanoparticles in atmospheric or low–pressure CVD reactors. Characterization of CNT forests dependence on CVD parameter space (temperature, gas flow, growth time, annealing effect) and catalyst nanoparticle size. Patterned deposition and characterization of CNT forest-Au nanoparticles hybrid nanostructures for surface–enhanced Raman scattering (SERS) sensing applications.
  - Growth of **Graphene** on Cu foil by atmospheric- and low-pressure CVD for electronic applications by using methane or xylene as a precursor.
  - Evaluation of graphene quality, domain, shape, and size, layers number dependence on CVD parameters such as growth temperature and time, gas concentrations.
  - Wet-chemical **Transfer of Graphene** to various substrates.
  - Transfer of Graphene/CNT films from Cu film/foil to desired substrate. Optical/Raman characterization of Graphene/layers.
  - Students trainings on hot-wall furnace, SEM, Graphene transfer/ Optical Microscopy

    Experimental Tools:

    Hot-wall CVD system (for CNT and 3rapheme growth), **plasma-assisted cold-wall CVD** (for CNT and 3rapheme growth), **SEM** (for characterization of CNT height and density, 3rapheme coverage, etc), **AFM** (for evaluating catalyst nanoparticles for CNT growth), **Optical Imaging** (for evaluating 3 rapheme layers), **Thermal Evaporation** and **Ion Sputtering** (for catalyst particles and supporting layers, patterned hybrid nanostructures preparation), **Raman microscopy** (for 3 rapheme layers/quality characterization, CNT/Au hybrid nanostructure enhancement evaluation.)

- **Heuristic Physics Laboratories (HPL)** Yerevan, Armenia
  *Internship, basics of **C++** Programming Language* *Feb. 2005 – July 2005*

  - Write codes using classes of *C++* for solving basic problems (e.g. the labyrinth problem).

- **ArWest Technologies** Yerevan, Armenia
  *Internship, **MatLab/Simulink*** *Jan. 2004 – Jan. 2005*

  - Design and implementation of RF Transmitter/Receiver communication system.

Publications

1. E. Satheeshkumar, **T. Makaryan**, A. Melikyan, H. Minassian, Y. Gogotsi, M. Yoshimura, One-step Solution Processing of Ag, Au and Pd@MXene Hybrids for SERS, ***Scientific Reports,*** 6, 32049 (2016)
2. P. Urbankowski, B. Anasori, **T. Makaryan**, D. Er, S. Kota, P. L. Walsh, M. Zhao, V. Shenoy, M. W. Barsoum, Y. Gogotsi, Synthesis of two-dimensional titanium nitride Ti4N3 (MXene), **Nanoscale**, vol 8, p. 11385 (2016)
3. Ren, C. E., Zhao, M., **T. Makaryan,**, Halim, J., Boota, M., Kota, S., Anasori, B., Barsoum, M. W. and Gogotsi, Y. Porous Two-Dimensional Transition Metal Carbide (MXene) Flakes for High-Performance Li-Ion Storage, **ChemElectroChem,** 3, 689 (2016)
4. Xie, X., **Makaryan, T.,** Zhao, M., Van Aken, K. L., Gogotsi, Y. and Wang, G. MoS_2 Nanosheets Vertically Aligned on Carbon Paper: A Freestanding Electrode for Highly Reversible Sodium-Ion

Batteries. **Adv. Energy Mater.**, vol. 6: p. 1502161, (2015)

5. S. Esconjauregui, **T. Makaryan**, T. Mirea, M. de-Miguel Ramos, J. Olivares, J. Yang, Y. Guo, S. Bhardwaj, H. Sugime, L. D'Arsié, C. Cepek, J. Robertson, E. Iborra, "Growth of carbon nanotube forests on AlN as top electrodes in electroacoustic resonators" ***Appl. Phys. Lett.,*** vol. 107, p. 133106 (2015)
6. J. Yang, S. Esconjauregui, H. Sugime, **T. Makaryan,** T. Hallam, G. Duesberg, J. Robertson, "Comparison of carbon nanotube forest growth using AlSi, TiSiN, and TiN as conductive catalyst supports" **Phys. Status Solidi** B, vol.251, p.2389, (2014)
7. H. Sugime, S. Esconjauregui, J. Yang, **T. Makaryan**, L. D'Arsié, J. Robertson, "Growth kinetics and growth mechanism of ultra-high mass density carbon nanotube forests on conductive Ti/Cu supports", ***ACS Applied Materials and Interfaces,*** vol.6(17) p.15440 (2014)
8. M.R. Gonçalves, A. Melikyan, H. Minassian, **T. Makaryan,** O. Marti, "Strong dipole-quadrupole coupling and Fano resonance in H-like metallic nanostructures," ***Optics Express,*** vol.22(20), p.24516 (2014)
9. J. Yang, S. Esconjauregui, R. Xie, H. Sugime, **T. Makaryan,** L. D'Arsié, D. L. G. Arellano, J. Robertson, "Effect of Oxygen Plasma Alumina Treatment on Growth of Carbon Nanotube Forests", ***J. of Physical Chemistry C***, vol.118(32), p.18683 (2014)
10. **T. Makaryan,** S. Esconjauregui, M. Gonçalves, J. Yang, H. Sugime, D. Nille, P. Renganathan, P. Goldberg, J. Robertson, "Hybrids of carbon nanotube forests and gold nanoparticles for improved surface plasmon manipulation," ***ACS Applied Materials and Interfaces***, vol. 6(8), p.5344, (2014)
11. S. Esconjauregui, S. Bhardwaj, J. Yang, C. Castellarin-Cudia, R. Xie, L. D'Arsié, **T. Makaryan,** H. Sugime, S. Eslava, C. Cepek, J. Robertson, "Carbon nanotube growth on conductors: influence of the support structure and catalyst thickness," ***Carbon***, vol.73, p.13, (2014)
12. H. Tornatzky, D. Hardeman, S. Esconjauregui, L. D'Arsié, R. Xie, H. Sugime, J. Yang, **T. Makaryan,** C. Thomsen, J. Robertson, "Evaluation of bimetallic catalysts for the growth of carbon nanotube forests," ***Physica Status Solidi B***, vol.250, p.2605, (2013)
13. M.R. Gonçalves, **T. Makaryan,** F. Enderle, S. Wiedemann, A. Plettl, O. Marti, P. Ziemann, "Plasmonic nanohole arrays fabricated using nanosphere-lithography, soft-lithography and plasma etching," ***Beilstein J. of Nanotechnology***, vol.2, p.448, (2011)
14. **T. Makaryan,** "Numerical simulations on longitudinal surface plasmons of coupled gold nanorods," ***J. of Contemporary Physics*** (Armenian Acad. of Sci.), vol.46(3), p.111, (2011)
15. **T. Makaryan,** "Influence of interface on surface plasmon frequencies of metallic nanosphere," ***Physica E:*** *Low-dimensional Systems and Nanostructures*, vol.43(1), p.134, (2010)
16. **T. Makaryan,** A. Melikyan, H. Minassian, "Surface Plasmon Frequency Spectrum in a System of Two Spherical Dielectric Coated Metallic Nanoparticles," ***Acta Physica Polonica A***, vol.112(5), p.1025, (2007)

Conference Contributions/Proceedings

1. V. Avetisyan, **T. Makaryan**, A. Makaryan. "Low-frequency noise in carbon nanotube thin films with disordered networks".
   *Contribution in "**Microwave and THz Technologies and applications**" in Aghveran, Armenia* *Oct. 2014*
2. M. Gonçalves, **T. Makaryan**, A. Melikyan, H. Minassian, O. Marti. "Dipole-quadrupole plasmon coupling and Fano resonance in nanorods of T-like configuration".
   *Contribution in "**German Physical Society**" in Dresden, Germany* *Apr. 2014*
3. M. Gonçalves, A. Melikyan, H. Minassian, **T. Makaryan**, O. Marti, "Dipole-quadrupole plasmon coupling and Fano resonance in nanorods of T-like configuration".

*Poster in "**Nanolight 2014**" in Benasque, Spain* *Mar. 2014*

4. H. Tornatzky, D. Hardeman, S. Esconjauregui, L. D'Arsié, R. Xie, H. Sugime, J. Yang, **T. Makaryan**, C. Thomsen, J. Robertson, "Evaluation of bimetallic catalysts for the growth of carbon nanotube forests".

*Poster in "**IWEPNM 13**" in Kirchberg, Austria* *Mar. 2013*

5. M.R. Gonçalves, **T. Makaryan**, A. Melikyan, H. Minassian, O. Marti, "Near-field patterns in sets of metal nanorods: Influence of the geometrical configuration on the field enhancement and far-field optical response".

*Poster in "**NFO 12**" in San Sebastian, Spain* *Sep. 2012*

6. M.R. Gonçalves, **T. Makaryan**, G. Papagiorgeou, O. Marti, "Near-Fields in Arrays of Triangular Particles: Coupling Effects and Field Enhancements".

*Contribution in "**Comsol 2011**" in Stuttgart, Germany* *Oct. 2011*

7. **T. Makaryan**, H. Minassian, A. Melikyan, "Optical Sensitivity of Noble Metal Nanorods".

Poster in "Laser Physics 2011" in Ashtarak, Armenia *Oct. 2011*

8. M.R. Gonçalves, **T. Makaryan**, T. Paust, O. Marti et al., "Near-field enhancement and light confinement in microcavities fabricated using soft-lithography and etching techniques".

*Contribution in "**Nanometa 2011**" in Tirol, Austria* *Jan. 2011*

9. **T. Makaryan**, "Surface plasmons in coupled metallic nanoparticles: numerical verification of new analytical approaches", Proc. of SPIE, vol.7998, p.79981E–1, (2011).

*Oral in "**Laser Physics–2010**" in Ashtarak, Armenia* *Oct. 2010*

10. **T. Makaryan**, K. Madoyan, A. Melikyan, and H. Minassian, "Theoretical study of surface plasmon frequencies in a system of two coupled spheres and comparison with experimental data", Proc. of SPIE, vol.7712, p.77121I, (2010).

*Oral in "**SPIE–Europe**" in Brussels, Belgium* *May 2010*

11. **T. Makaryan**, A. Melikyan, and H. Minassian,"Impact of interface on surface plasmon frequencies of metallic nanosphere", Proc. of the Conf. "Laser Physics 2007", p.213, (2007).

*Poster in "**Laser Physics–2007**" in Ashtarak, Armenia* *Oct. 2007*

Awards/Grants

- **Grant** for Experimental and Theoretical Study of Surface Plasmons in Metallic Nanoparticles
  *Joint project with the University of Ulm, from "**Volkswagen Stiftung**"* *June 2013*
- **Presidential Award** for "**Best PhD Student** of Armenia in **IT** sphere"
  Synopsys Armenia, Inc. *Oct. 2011*
- **Grant** in the scope of "Young Scientists Research Assistance Project"
  State Council of Science of Armenia *Apr. 2011*
- **Grant** for studying "**Advanced Materials**" in the **University of Ulm, Germany**
  *German Academic Exchange Program (**DAAD**)* *Aug. 2008 –Sep. 2010*
- **Award** as Winner of "**Best Student - 2006**" Competition, Gold Medal
  Yerevan State University, Armenia *Aug. 2006*

Skills

Languages: English (fluent); Russian (good); German (good), Armenian (native)

PC Software: COMSOL RF Module; DDSCAT; C; NI LabView; MatLab Simulink; MathCad; LATEX; OriginPro, WiTec, WiRE