APPLICATIONS OF NANOGAPS ON-A-CHIP FOR THE DEVELOPMENT OF NEW GENERATION OF BIOMACROMOLECULAR AND NOVEL NANOMATERIALS DETECTION AND ANALYSIS METHODS

Leonardo Lesser-Rojas


This talk reports advances on a versatile platform for manipulation, positioning and sensing of biomacromolecules and solid-state nanomaterials based on dielectrophoresis (DEP), which can function as AC DEP-based molecular trapping templates, electronic readers, and hot spots for surface enhanced Raman spectroscopy (SERS) [1], further demonstrated for low-copy number detection of biomacromolecules using an Electrical Auto-Correlation Spectroscopy (ECS) technique to elucidate biophysical parameters [2], the development of analytical tools to study the undergoing structural conformation changes of amyloid beta (Aβ) peptides [3, 4], and the magnetosensitive-driven structural conformation and electronic charge transfer behavior of the Cryptochrome-1 CRY1 protein present in migratory bird and insect species [5], as some examples of its applications. Furthermore, the undergoing work related to characterizing the opto-electronic and vibrational properties of germanium-based organometallic compounds and the binding and conformational properties of lanthanide series (Ln) rare earth metal-binding proteins, will be briefly discussed. Our platform opens up a simple way for multifunctional quantification of low-concentration heterogeneous sample and biomacromolecular and nanomaterial’s analysis.

References:


**Keywords:** Nanobioscience and technology, Multifunctional Analysis, Surface Enhanced Raman Spectroscopy

**Acknowledgment:**

This material is partially based upon work supported by the Air Force Office of Scientific Research under award number FA9550-21-1-0430

**Presenting authors email:** leonardo.lesser@ucr.ac.cr
BIOGRAPHICAL SKETCH

NAME
Leonardo Lesser-Rojas, Ph.D.

E-MAIL
leonardo.lesser@ucr.ac.cr

POSITION TITLE
Associate Professor, Principal Investigator
Research Center for Atomic, Nuclear and Molecular Sciences
School of Physics, Universidad de Costa Rica

EDUCATION/TRAINING

<table>
<thead>
<tr>
<th>INSTITUTION AND LOCATION</th>
<th>DEGREE (if applicable)</th>
<th>MM/YY</th>
<th>FIELD OF STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Costa Rica, San José, Costa Rica</td>
<td>B.Sc.</td>
<td>10/2002</td>
<td>Mechanical Engineering</td>
</tr>
<tr>
<td>University of Costa Rica, San José, Costa Rica</td>
<td>M.Sc.</td>
<td>08/2006</td>
<td>Mechanical Engineering</td>
</tr>
<tr>
<td>National Tsing Hua University and Institute of Physics, Academia Sinica, Taipei, Taiwan-R.O.C.</td>
<td>Ph.D.</td>
<td>04/2014</td>
<td>Engineering Science (Engineering Physics) with emphasis in Nanoscience and Technology</td>
</tr>
<tr>
<td>Academia Sinica, Taipei, Taiwan-R.O.C.</td>
<td>Post-doctoral fellowship</td>
<td>07/2014</td>
<td>Nanobioscience and Technology</td>
</tr>
</tbody>
</table>

A. Personal Statement (description of his/her research interests and cooperation)

Professor Lesser-Rojas (aged 45) is a Costa Rican specialist in the area of nanobioscience and nanobiotechnology and gathers knowledge in the development of nano and micro-electro-fluidic technologies fabricated on chip devices, towards the advancement of detection, analysis and assembly platforms for biomacromolecular, cell and nanoparticle-based functional materials. Since joining his Alma Mater UCR in 2015 and the foundation of the Nano Bio Systems Laboratory (https://lananbios.wordpress.com) at the Research Center for Atomic, Nuclear and Molecular Sciences (LANANBIOS-CICANUM) in 2016, he has ventured thanks to the support of government funds in the development of microfluidic devices used for the preconcentration and manipulation of bacterial and cellular samples using combined electrokinetic methods, as well as in cooperation projects for the development of nanoscale biosensors for biomacromolecular electronic and spectroscopic detections, with applications ranging from the study of structural conformation changes of amyloid beta peptides and the detection of bacterial spores using aptamer-coated graphene, to the characterization of magneto-sensitive proteins in migratory butterflies, being a beneficiary of Incentive Funds for Frontier Scientific Research (2016), Funds for Research projects in partnership with Germany (2018); which were financially supported by the Ministry of Science, Technology and Telecommunications (MICITT) of Costa Rica and the German Federal Ministry of Education and Research (BMBF) and an AFOSR/ONRG/DEVCOM tri-party grant awardee (2021). He is also exploring new fields towards the development and characterization of new nanoparticle-based functional materials as well as new uses for microfluidic devices with applications that range from bone tissue regeneration engineering and the assembly of bio-inspired drug delivery nanoemulsions to new generation perovskite solar cells and on-chip biomining. His nano and micro systems open up applications for multi-functional molecular and cell level as well as solid state materials sample analysis with simultaneous characterizations at the single/few molecules/cell/nanoparticles level. Keywords: Nanobiotechnology, nano and micro fabrication, biosensors, nanoelectronics, electrokinetics, Biophotonics, Surface Enhanced Raman Spectroscopy, Computational Multiphysics simulations, lab-on-chip systems (µTAS), microfluidics, nanoparticle-based functional materials.

B. Positions and professional career

- Associate Professor, School of Physics, University of Costa Rica, Principal Investigator of the Laboratory of Nano Bio Systems (LANANBIOS) and Sub-Director at the Research Center for Atomic, Nuclear and Molecular Sciences (CICANUM), University of Costa Rica (2018-present, Faculty position).
- Invited Professor, School of Physics, University of Costa Rica (2015-2017, Tenure track position).
- Adjunct Lecturer at the Schools of Physics and Mechanical Engineering, University of Costa Rica. (Aug 2014–present, Faculty position).  
- Postdoctoral Fellow, Nanobioscience Lab, Institute of Physics, Academia Sinica, Taiwan R.O.C. (April–July 2014).
- Visiting researcher at the Interface Spectroscopy Group, Max-Planck-Institut für Eisenforschung GmbH (MPIE), Düsseldorf Germany (Oct 2011-Jan 2012).
- Adjunct Professor at the School of Industrial Engineering of the University of Costa Rica (2004).

Others:
- Active member of the MicroTAS community since 2018, served as a Conference Official in the MicroTAS 2020 Online.
- Reviewer for several prestigious peer-reviewed international journals that include among others Biomicrofluidics and Electrophoresis as well as an external grant reviewer for local and international government funding agencies such as CONARE-Costa Rica and CONCYTEC-Perú.
- Scientific Advisor Board Member at Costa Rica’s National Laboratory of Nanotechnology (LANOTEC).
- Associate member of the Costa Rican Board of Engineers and Architects (CFIA), IM-15834.
C. Ongoing and Past Research Projects

C0511 "Investigating energy transfer phenomena in novel organometallic nanomaterials and metal-binding biomacromolecules using electrode nanogap-enabled, DEP-assisted electronic and spectroscopic measurement" (2021-2024). Funded by AF Office of Scientific Research (AFOSR), United States. Principal Investigator.


B7512. High Sensitivity Sensors based on biofunctionalized graphene for the detection of Clostridium Difficile. Collaboration with Max-Planck Institute of Solid State Research (MPIFKF) Stuttgart, Germany. Ongoing (01/2017-01/2021). Funded by MICITT and BMBF Germany. Associate


D. Selected Peer-reviewed Publications and Patents

L. Lesser-Rojas, et.al. (2014) "Tandem array of nanoelectronic readers embedded coplanar to a fluidic nanochannel for correlated single biopolymer analysis". Biomicrofluidics, 8, 016501.


