Nick J. Carroll, Ph.D.
Assistant Research Professor
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My primary research focus is programming soft materials at the building block level (e.g. genetic, molecular, fluidic) for self-assembly into functional colloidal architectures. Investigations of soft materials include microfluidic assembly, genetic programming of polypeptide self-assembly, phase behavior studies and polymer physics. These encoded materials span the nano- to micro-scale, finding utility in regenerative medicine, cell patterning, drug delivery, and bioanalytical systems.

EDUCATION

Postdoctoral Fellow, Applied Physics, Harvard University, 2011-2014 (2 years 3 months).
Ph.D., Chemical Engineering, *with distinction*, University of New Mexico, 2006-2011.
B.S., Chemical Engineering, *summa cum laude*, University of New Mexico, 2003-2006.

RESEARCH EXPERIENCE

Assistant Research Professor, *Duke University*, February 2014-Present: Programming phase behavior of genetically engineered polypeptides and polypeptide fusions to enable self-assembly into supramolecular nano- to microscale structures. Polymer science. Microfluidics.

- Development of self-assembled protein granules with controllable size (nano- to microscale), composition (single component, blends) and architectures (e.g. multilayer particles).
- Design of elastin-like polypeptide microgels incorporating cell integrin-binding domains as 3D scaffolds for cell culture.
- Creating cellular microarrays using genetically engineered gold- and cell-binding polypeptides.
- Extended and tunable delivery of protein therapeutics (e.g. glucagon-like peptide-1) through programming of genetically engineered polypeptide granular assemblies for diabetes treatment.
- Mapping the phase diagram of LCST elastin-like polypeptides using light scattering techniques.
- Post-production conjugation of polypeptides with photoisomerable chromophores for light-stimulus induced modulation of protein granule phase and wetting behavior.
- Using gold-binding polypeptides and droplet microfluidics to fabricate protein granule/gold nanorod composites for light-stimulus (near-IR) heating and drug release.
- Droplet microfluidics for fabrication of acoustic- and magnetic-responsive elastomers for bioseparation applications.

Postdoctoral Fellow, *Harvard University*, October 2011-January 2014: Emulsion, microfluidic, and polymer materials science research developing smart microcapsules for oil reservoir, drug delivery, and sensing applications.

- Development of robust capsule packaging with clocking release mechanism for delivery of molecular cargo within simulated oil reservoir environments.
- Fabrication of smart capsules for stimuli-triggered release: oil triggerable and pH sensitive capsules by integrating double emulsion templates and advanced polymeric science.
- Study of microcapsule delivery within porous media for enhanced oil recovery simulations.
- Programming self-assembly of particles with hierarchical architecture.
- Theoretical microfluidics exploiting fluorescence photobleaching for non-invasive estimation of molecular diffusivity and associated fluid viscosity.

Graduate, *University of New Mexico*, 2006-2011: multidisciplinary research with concentration on polymerization in microdroplet reactors for synthesis of complex nanostructured materials and development of DNA assays.

- Developed novel approach for the synthesis of hierarchically porous, nanostructured microparticles by simultaneous templating with nanoemulsion and molecular surfactant phases.
- Tailored porous architectures of microparticles for practical application in drug delivery and catalysis applications.
- Integrated droplet-based microfluidics, emulsion PCR, and fluorescent molecular beacon probes to develop assay for detection of mRNA splice variants in human Leukemia cells.
- Synthesis of monodisperse, nanoporous silica microparticles using molecular self-assembly and droplet-based microfluidics.

Research Internship, *Harvard University*, summer 2006

- Utilized anhydrous chemistries in droplet-based microfluidics for synthesis of monodisperse polyurethane microspheres. Included synthesis of novel surfactant for fluorocarbon emulsions.

Undergraduate, *University of New Mexico*, 2005-2006

- Experimental: molecular separations via pressure driven flows in nanochannels.

AWARDS

Graduate fellow, NSF UNM/Harvard PREM, 2009, 2010.
Graduate fellow, NSF IGERT INCBN, 2007, 2008.
Scholarship, Border's Group Foundation Award, 2007-2008.
Outstanding Junior Award, UNM chemical engineering, 2005.

RESEARCH

I. Manuscripts in Preparation

1. J. R. Simon[#], **N.J. Carroll**[#*], A. Chilkoti, M. Rubinstein and G.P. López[*], ([#]=equal contributors), "Programmable Liquid-Liquid Compartments Comprised of Genetically Engineered Intrinsically Disordered Proteins" in preparation: *Nature*, 2016.

2. L. Li, C-K. Mo, A. Chilkoti, G.P. López[*], and **N.J. Carroll**[*], "Creating Cellular Microarrays Using Genetically Engineered Gold- and Cell-Binding Polypeptides" *Submitted* to *Biointerphases*, 2016.

3. A. Ghoorchian, Kevin Reed, G.P. López, and **N.J. Carroll**[*], "Biodegradable Capsule Microreactors with Selectively Permeable Membranes for Fabrication of Polypeptide Hydrogels" in preparation, 2016.

4. **N.J. Carroll*** and M. Rubinstein, "Phase Behavior of Aqueous Elastin-Like Polypeptide Mixtures." In Preparation: Macromolecules, 2016.

([*]=corresponding author)

II. Peer-Reviewed Publications

1. M. Zieringer[#], **N.J. Carroll[#]**, A. Abbaspourrad and D.A. Weitz, ([#]=equal contributors) "Microcapsules for Enhanced Cargo Retention and Diversity," *Small*, *Published online Feb18*, 2015.

2. **N.J. Carroll[#]**, K. H. Jensen[#], S. Parsa, N.M. Holbrook and D.A. Weitz ([#]=equal contributors), "Measurement of Flow Velocity and Inference of Liquid Viscosity in a Microfluidic Channel by Fluorescence Photobleaching," *Langmuir*, **30**, 4868–4874, 2014.

3. A. Abbaspourrad, **N.J. Carroll**, S.-H. Kim and D. A. Weitz, "Polymer Microcapsules with Programmable Active Release," *Journal of the American Chemical Society*, **135**, 7744–7750, 2013.

4. **N.J. Carroll,** P. Crowder, S. Pylypenko, W. Patterson, D.R. Ratnaweera, D. Perahia, P.B. Atanassov and D.N. Petsev, "Microfluidic Synthesis of Monodisperse Nanoporous Oxide Particles and Control of Hierarchical Pore Structure" *ACS Applied Materials & Interfaces,* **5**, 3524-3529, 2013.

5. A. Abbaspourrad, **N.J. Carroll**, S.-H. Kim, and D. A. Weitz, "Surface Functionalized Hydrophobic Porous Particles Toward Water Treatment Application," *Advanced Materials*, **25**, 3215–3221, 2013.

6. K.W. Cushing, M.E. Piyasena, **N.J. Carroll**, G.C. Maestas, B.A. López, B.S. Edwards, S.W. Graves, and G.P. López, "Elastomeric Negative Acoustic Contrast Particles for Affinity Capture Assays," *Analytical Chemistry*," **85**, 2208—2215, 2013.

7. **N.J. Carroll** and D.N. Petsev "Microfluidics for Particle Synthesis", in *Topics in colloidal aggregation and interfacial phenomena*, M. Garcia-Sucre, J. Toro-Mendoza, A. Castellanos-Suarez and A. Lozsan, Editors (Res. Signpost, 2012).

8. **N.J. Carroll**, S.-T. Chang, D.N. Petsev, and O.D. Velev, "Droplet Microreactors for Materials Synthesis", in *Microdroplet Technology: Principles and Applications in Biology and Chemistry*, P. J. R. Day, Y. Zhang and A. Mainz, Editors (Springer, 2012).

9. C.E. Ashley, E.C. Carnes, G.K. Phillips, D. Padilla, P.N. Durfee, P.A. Brown, T.N. Hanna, J. Liu, B. Phillips, M.B. Carter, **N.J. Carroll**, X. Jiang, D.R. Dunphy, C.L. Willman, D.N. Petsev, D.G. Evans, A.N. Parikh, B. Chackerian, W. Wharton, D.S. Peabody, and C.J. Brinker, "The Targeted Delivery of Multicomponent Cargos to Cancer Cells by Nanoporous Particle-Supported Lipid Bilayers," *Nature Materials*, **10**, 389-397, 2011.

10. S. Pylypenko, T.S. Olson, **N.J. Carroll**, D.N. Petsev, and P.B. Atanassov, "Templated Platinum/Carbon Oxygen Reduction Fuel Cell Electrocatalysts," *Journal of Physical Chemistry C*, **114**, 4200-4207, 2010

11. **N.J. Carroll**, S. Pylypenko, P.B. Atanassov and D.N. Petsev, "Hierarchical Nano Porous Microparticles Derived by Microemulsion Templating," cover art of *Langmuir*, **25**, 13540–13544, 2009.

12. **N.J. Carroll**, S. Mendez, J.S. Edwards, D.A. Weitz, and D.N. Petsev, "Droplet-Based Microfluidics: Picoliter-Sized Reactors for Mesoporous Microparticle Synthesis," in "Structure and Functional Properties in Colloidal Systems," R. Hidalgo-Alvarez, Editor (Taylor & Francis), 2009.

13. **N.J. Carroll**, S.B. Rathod, E. Derbins, S. Mendez, D.A. Weitz, and D.N. Petsev, "Droplet-Based Microfluidics for Emulsion and Solvent Evaporation Synthesis of Monodisperse Mesoporous Silica Microspheres," *Langmuir*, **24**, 658, 2008.

PATENTS

U.S. Patent No: 8,334,013: "*Droplet Based Microfluidics for Emulsion and Solvent Evaporation Synthesis of Monodisperse Mesoporous Silica Microspheres"* developed by N.J. Carroll, S.B. Rathod, E. Derbins, S. Mendez, D.A. Weitz and D.N. Petsev.

U.S. Patent No: 8,334,014: *"Microparticles with Hierarchical Porosity"* developed by Nick. J. Carroll, S. Pylypenko, P. Atanassov and D.N. Petsev.

U.S. Patent No: 8,658,734 "*Synthesis of Stable Elastomeric Negative Acoustic Contrast Particles*" developed by K. Cushing, N.J. Carroll, D.N. Petsev and G.P. López.

U.S. Patent No: 8,911,864 *"Monodispersed Particles Fabricated by Microfluidic Device"* developed by N.J. Carroll, A. Ortiz, S. Pylypenko, P. Atanassov and D.N. Petsev.

U.S. Patent Application No: 61/728,478 "*Particles for Uptake or Sensing of oil and other applications, and related methods*" developed by A. Abbaspourrad, N.J. Carroll and D.A. Weitz.

U.S. Patent Application No: 61/768,206 "Nanostructured Active Therapeutic Vehicles and Uses Thereof" developed by K.K. Parker, J.U. Lind, D. A. Weitz, N.J. Carroll and A. Abbaspourrad.

U.S. Patent Application No. 61/857,834 "Hydrophobic Cross-linked Microcapsule Shells for Long-Term Storage and Triggered Release of Encapsulated Actives" developed by N.J. Carroll, M. Zieringer, D. A. Weitz.

U.S. Provisional Patent Filed October 15, 2014 "Programmable Liquid, Gel, and Biohybrid Compartments" developed by N.J. Carroll, J. Simon, A. Chilkoti, G.P. López

TEACHING AND MENTORING

I. Teaching Experience

Lecturer (Duke):

- BME307, Transport in Biological Systems, Spring 2014, Spring 2015

Teaching Assistant (UNM):

- Transport Phenomenon (graduate and undergraduate)
- Chemical Engineering Thermodynamics
- Chemical Process Calculations I

II. Research Mentor

1. Simon Mo (Duke)
2. Kevin Reed (Duke)
3. Charles Leo (Duke)
4. Alice Li (Duke)
5. Joe Lamas (Duke)
6. Pearlson Prashanth (Duke)
7. Kenneth Ho (Harvard)
8. Cuiping Zhang (Harvard)
9. Peter Crowder (UNM)
10. Amber Ortiz (UNM)
11. Erin Derbins (UNM)
12. Ciana López (UNM)
13. Carmen Martinez (UNM)

III. Dissertation Committee Member

1. Alice Li (Duke)
2. Isaac Weitzhandler (Duke)