The fundamental operation of many semiconductor nanowire devices rely on the ability to controllably modulate the composition to create both heterostructures as well as homogenously-doped and modulation-doped nanowires with compositionally-abrupt junctions. However, controlled doping with electronic impurities remains an important challenge in large part due to a lack of a technique or tool sensitive enough to directly quantify the distribution and dopant concentration in individual nanowires. In this talk, I will discuss use of atom probe tomography (APT) to map the 3D dopant distribution and directly reveal an axially and radially inhomogeneous P and B dopant distribution in individual vapor-liquid-solid (VLS) grown Si and Ge nanowires. We show that the dopant inhomogeneity is due to two kinetically distinct incorporation pathways: 1) incorporation into the nanowire core via the liquid catalyst, 2) incorporation directly into the nanowire surface via thin-film deposition. Considering the stoichiometric dopant/semiconductor ratio in the gas-phase, we find the nanowire core to be substantially underdoped while the surface is substantially overdoped. Dopant depletion studies along the nanowire growth axis reveal a long depletion profile of hundreds of nanometers which is much longer compared to the Si-Ge heterojunction width which is on the order of the nanowire diameter. A dopant incorporation model suggests that the interfacial width depends on the solute solubility in the liquid catalyst. As VLS growth of a nanowire heterostructure, composed of species A and B, is mediated through a liquid metal alloy nanoparticle, the transition region width is dictated by the depletion rate of species A from the liquid, which in turn is dictated by its relative solubility in the liquid. I will further discuss a new approach of using a low-solubility liquid Ga-Au alloy catalyst to create a sharper axial heterojunction in Ge-Si, relative to that obtained using pure Au. By lowering the solubility of Ge within the liquid Ga-Au alloy catalyst, we show for the first time, the formation of a progressively sharper Ge-Si heterojunction. The sharper interface corresponds to a progressively lower Ge solubility in the Ga-Au alloy. This work provides motivation to further explore alternative catalyst metals and metal alloys with Au in order to tailor interfacial abruptness in modulation-doped heterostructures (eg. p-n junctions).

Biosketch
Daniel Perea is a Director’s Fellow Postdoc with Tom Picraux at the CINT Gateway facility. He recently graduated with his Ph.D. in Materials Science & Engineering from Northwestern University. His background is in the CVD growth and nanoscale compositional mapping of semiconducting nanowires and magnetic thin films. His current research interests include using Atom Probe Tomography to map the 3D composition of individual nanowires to understand the limits of in situ dopant incorporation in as well using novel alloy catalysts to control axial interfacial abruptness of nanowire p-n hetero- and homojunctions. Daniel is also collaborating with peers within CINT to fabricate electronic devices from individual heterostructured nanowires in order to correlate the electronic transport properties with the 3D composition so as to better understand the structure/properties relationship.