EILERS GRADUATE STUDENT FELLOWSHIP
FINAL REPORT

EILERS FELLOW:	Agust Olafsson
FACULTY ADVISOR:	Jon Camden
REPORT PERIOD:	Feb 2021 – Aug 2021
PROJECT TITLE:	Infrared nano-spectroscopy of plasmonic materials using high-resolution STEM-EELS
CONNECTION TO ND ENERGY'S RESEARCH AREAS (CHECK ALL THAT APPLY):	**(X) Energy Conversion and Efficiency ( ) Sustainable and Secure Nuclear** **(X) Smart Storage and Distribution ( ) Transformation Solar** **( ) Sustainable Bio/Fossil Fuels ( ) Transformative Wind**

MAJOR GOALS AND ACCOMPLISHMENTS:
List your major research goals and provide a brief description of your accomplishments (1-2 sentences). Indicate the percentage completed for each goal. Please use a separate sheet to share additional details, technical results, charts, and graphics.

MAJOR RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Examine dopant concentration effects on NC plasmons	Measured the effects of dopant concentration on hybrid plasmon modes in the infrared regime.	75
Image NC-NC plasmon hybridization	Analyzed the hybridized modes of indium tin oxide nanocrystal (NC) dimers at various tin dopant concentrations.	100
Measure NC optical constants	Used electron energy loss (EELS) to measure optical constants of ITO with varying tin dopant and simulate monomer and dimer plasmon modes.	25

RESEARCH OUTPUT:
Please provide detailed information below regarding any output resulting from your research project.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount) Air Force Office of Scientific Research, "Direct Observation of Infrared Energy Transfer Using Focused Electron Beams", Jon Camden and David Masiello, March 2021, $550,118.00
EXTERNAL AWARDS	(Sponsor, Project Title, PIs, Award Date, Award Amount) Air Force Office of Scientific Research, "Direct Observation of Infrared Energy Transfer Using Focused Electron Beams", Jon Camden and David Masiello, March 2021, $550,118.00
JOURNAL ARTICLES	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s) *In Submission,* "Imaging Infrared Plasmon Hybridization in Doped Semiconductor Nanocrystal Dimers", Agust Olafsson, Siamak Khorasani, Jacob Busche, Jose Araujo, Juan Carlos Idrobo, Daniel Gamelin, David Masiello, Jon Camden. *Nano Letters*, "Electron Beam Infrared Nano-Ellipsometry of Individual Indium Tin Oxide Nanocrystals", Agust Olafsson, Jacob A. Busche, Jose J. Araujo, Arpan Maiti, Juan Carlos Idrobo, Daniel R. Gamelin, David J. Masiello, and Jon P. Camden. September 2020, 20, 11, 7987–7994
BOOKS AND CHAPTERS	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s) N/A
PUBLIC PRESENTATIONS, SEMINARS, LECTURES	(Event, Presentation Title, Presentation Date, Location) *Planned Presentation*, Imaging plasmon hybridization in semiconductor nanocrystals. Pacifichem. Dec 2021.
AWARDS, PRIZES, RECOGNITIONS	(Purpose, Title, Date Received) N/A
INTERNAL COLLABORATIONS FOSTERED	(Collaborator Name, Organization, Purpose of Affiliation) N/A
EXTERNAL COLLABORATIONS FOSTERED	(Collaborator Name, Organization, Purpose of Affiliation) Daniel R. Gamelin, University of Washington, Synthesis of Semiconductor Nanocrystals
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL) N/A
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail) N/A

MAJOR GOALS AND ACCOMPLISHMENTS

(Additional Details, Technical Results, Charts and Graphics)

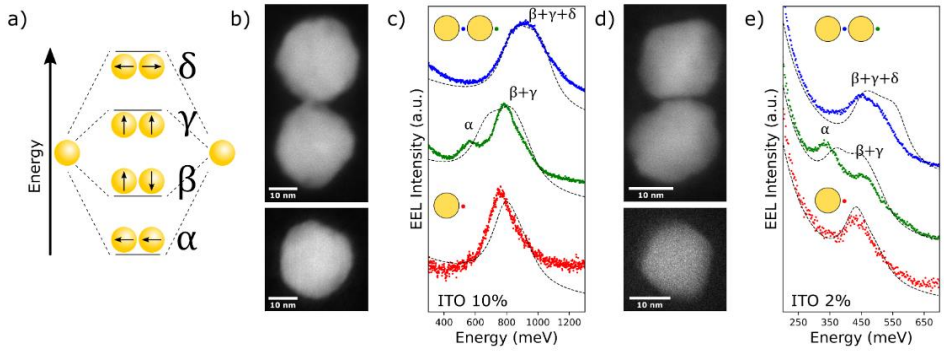

Figure 1: Surface plasmon hybridization of ITO NC dimers. The hybridization diagram (a) depicts the collinear in-phase (α), perpendicular in-phase (β), perpendicular out-of-phase (γ), and collinear out-of-phase (δ) coupled modes. TEM images of the 10% Sn^{4+} (b) and 2% Sn^{4+} (d) doped ITO NC samples studied. Experimental EEL point spectra (c,e) collected at the aloof positions of the monomer (red), dimer end (green), and dimer gap (blue) together with corresponding simulated EEL spectra (black dash). The rising feature at low energy is the zero loss peak tail (SI).

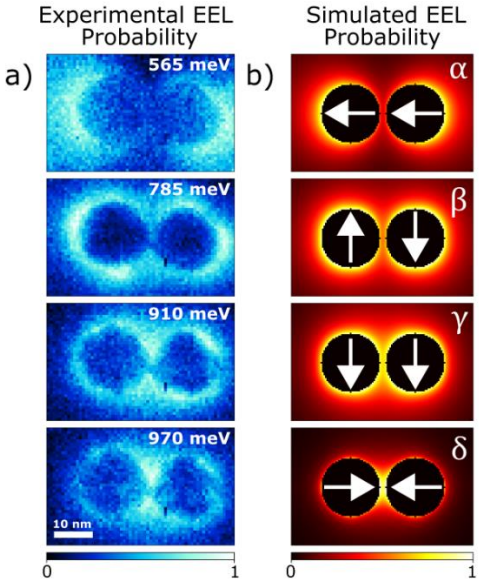

Figure 2: EEL spectrum images displaying IR plasmon hybridization in a 10% ITO NC dimer. The experimental (a) and simulated (b) images demonstrate each of the four hybrid dipolar modes (α,β,γ,δ). The subtle difference between perpendicular modes β and γ is indicated by the node of low probability in the β mode junction that is absent in the γ mode junction.

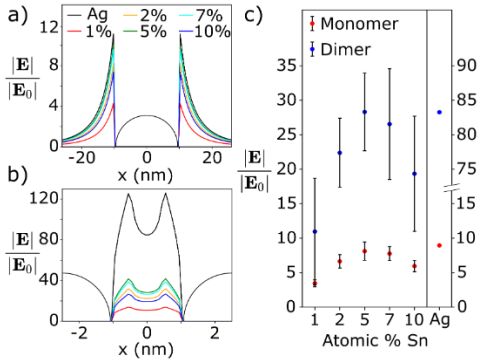

Figure 3: Simulated electric field enhancement in ITO NCs as a function of tin dopant concentration. Line scans show the maximum field enhancement for an ITO monomer (a) and dimer (b) compared to silver, all computed at their respective resonance energy. For both ITO monomers and dimers, the maximum field enhancement (c) occurs at 5% tin doping. Error bars indicate the standard deviation from the mean.[24]