SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Brian Kang
FACULTY ADVISOR:	Prashant Kamat
PROJECT PERIOD:	November 30 - February 2
PROJECT TITLE:	
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**(X) Energy Conversion and Efficiency** **( ) Sustainable and Secure Nuclear** **( ) Smart Storage and Distribution** **(X) Transformation Solar** **( ) Sustainable Bio/Fossil Fuels** **( ) Transformative Wind**

MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED

RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS SUBMITTED	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount)
EXTERNAL AWARDS RECEIVED	(Sponsor, Project Title, PIs, Award Date, Award Amount)
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	(Event, Presentation Title, Presentation Date, Location)
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
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)

RESEARCH EXPERIENCE

Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?

The experience was much needed and very educational. I learned more about a field of topic that I have had interest in since my freshman year. It was interesting to learn all the machinery and thought-processes of how research is conducted, especially with the guidance of other graduate students. Overall, this period of time was enlightening and I hope to continue on what I worked on more, now that I have more structure and based knowledge of the laboratory itself.

FINAL WRITTEN REPORT

(Please use the space below to describe your research project and objectives, any findings and results you can share, and graphs, charts, and other visuals to help us understand what you achieved as a result of this research experience.)

During this research experience, there was a lot of initial exploratory research in order to determine guidance for the time being and for subsequent periods of research.

Brian Kang
Vincent P. Slatt Fellowship

Undergraduate Research in Energy Systems and Processes, ND Energy
Department of Chemical and Biomolecular Engineering

Perovskite material is fairly new and is a promising pathway for solar energy applications. Solar cell efficiencies based on perovskite material have much higher maximum efficiencies than the normal single-junction silicon solar cells. This is primarily due to its cost-effectiveness and its strong light absorption properties. The raw material is cheap, allowing for more profit and lower cost. The high absorption ability allows for incredibly thin films to be made that still allow for the absorption of the light spectrum. However, these benefits come with disadvantages that must be solved before being able to fully rely on perovskite material as the basis for solar cells.

Chemically, the formula for perovskite can be generalized to ABX_3. Perovskite properties differ by either altering the halide ions (represented by "X" in the general form) or the cations (which are represented by "A" in the general form). For instance, in the following research, the difference between the halides bromine and iodine is explored in terms of its effect on the perovskite's stability and absorption. The halide ions are extremely mobile and unstable, which poses a problem in the real-world application. However, cations are less mobile and are much more stable, which is why the study of cation chemistry and its effect on the flow of charge carriers is important in regards to perovskite.

During this research experience, there was a lot of initial exploratory research in order to determine guidance for the time being and for subsequent periods of research. With a lot of trial and error, synthesis for formamidinium lead bromide ($FAPbBr_3$), cesium lead bromide ($CsPbBr_3$) formamidinium lead iodide ($FAPbI_3$), and cesium lead iodide ($CsPbI_3$) films were finalized. The synthesis of perovskite films depends on many variables. During the research period, we explored more of how different concentrations of stock solutions, methodologies of spin-coating, annealing periods, and other factors affect the resulting perovskite cells. The perovskite films created were tested by implementing an absorbance test. The two films, the formamidinium and the cesium, were clamped together and heated to a certain degree of heat, which ranged from 100℃ to 200℃. This is because using heat will accelerate the halide migration across the films. However, it was difficult to find the ideal temperature at which the two films should be set together at. This is why many different tests were run at varying temperatures for both the iodine and bromine films. The results are depicted in the following figures, and are some of the best demonstrations of the ideal cation migration without any degradation.

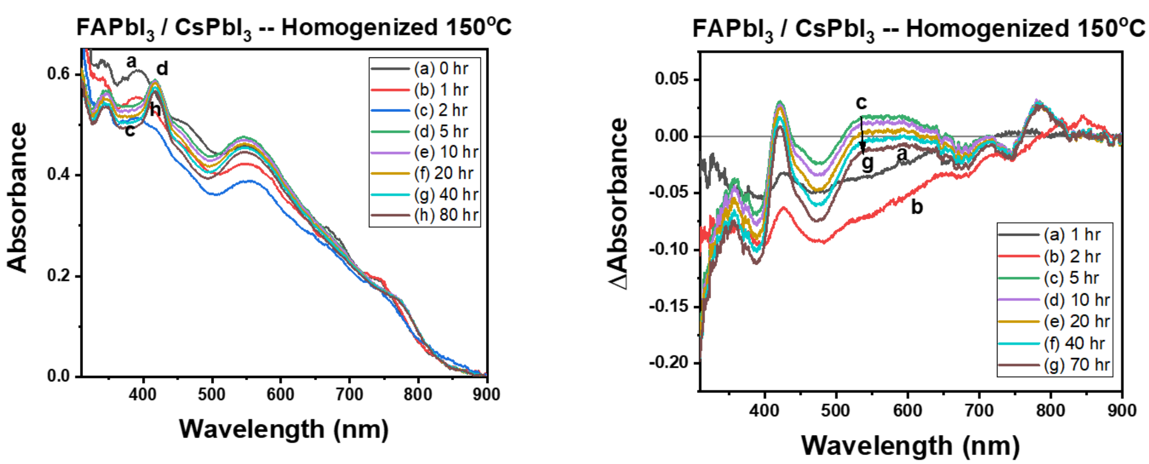


Figure 1.1 Absorbance Spectra of $CsPbBr_3$ and $FAPbBr_3$

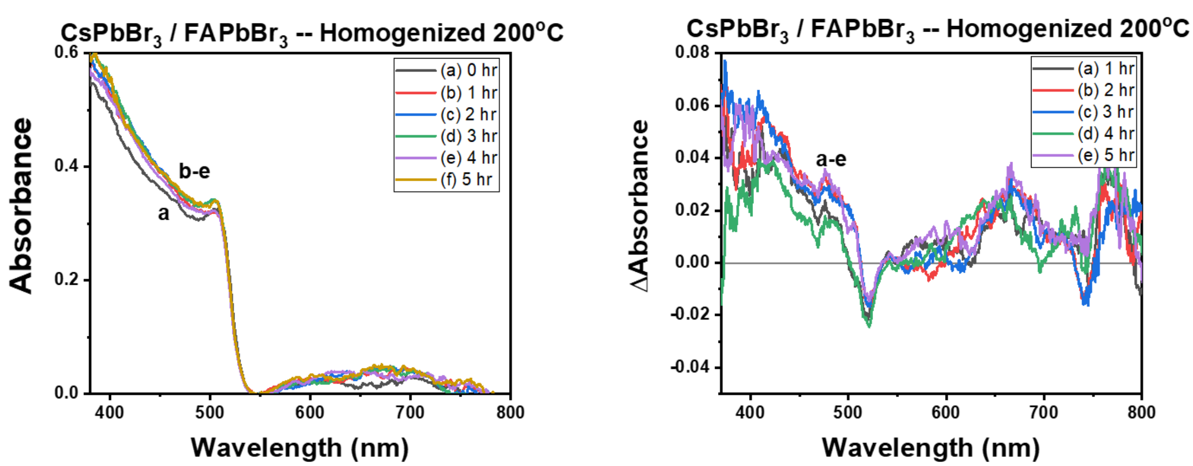
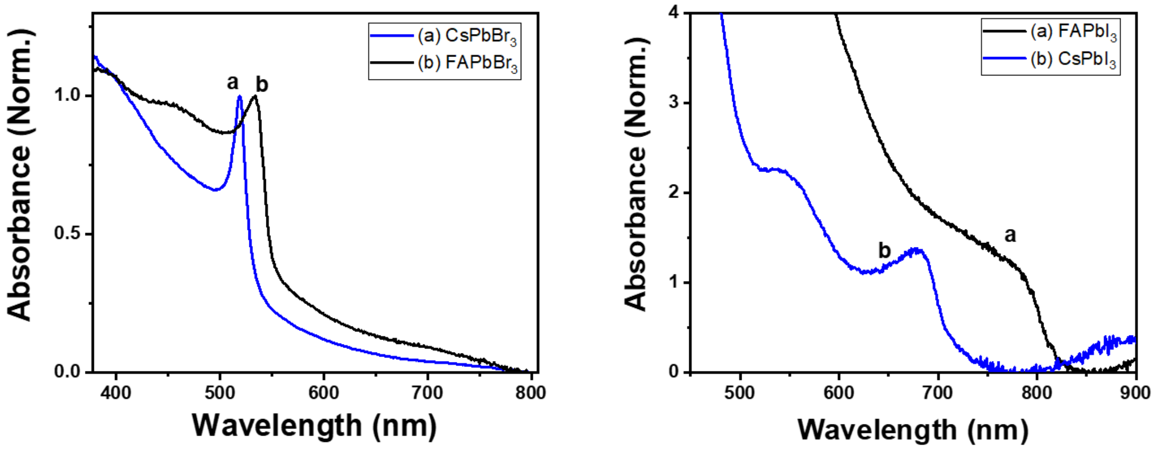


Figure 1.2

Absorbance Spectra of $CsPbI_3$ and $FAPbI_3$

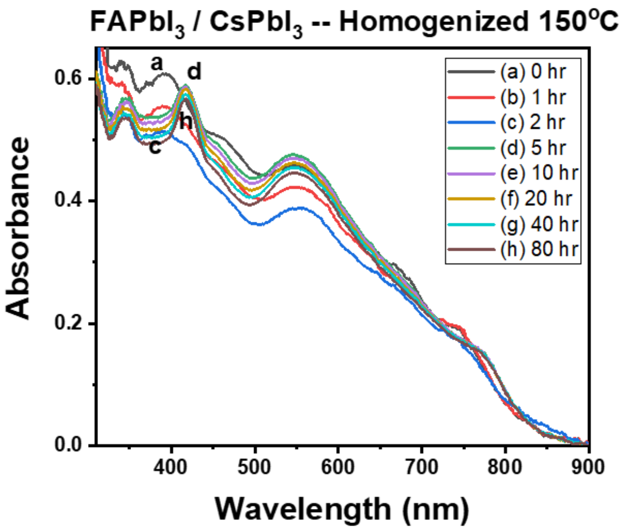
These results can be compared to the separate absorbance spectra of each of the films. This is because we can see more prominently how the migration occurs and how the peaks merge together, compared to their separate peaks depicted in the graphs shown in Figure 2.



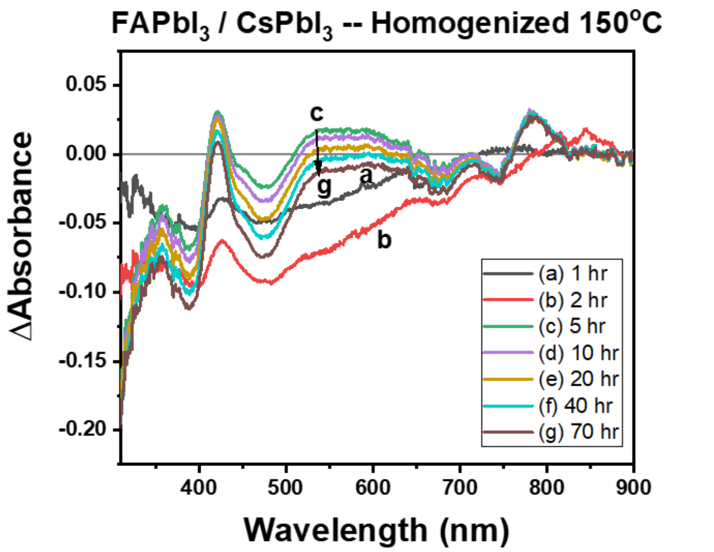
Absorbance spectra of $CsPbBr_3$, $FAPbBr_3$, and $CsPbI_3$, $FAPbI_3$ perovskite films

Figure 2. Absorbance Spectra of $CsPbBr_3$, $FAPbBr_3$, $CsPbI_3$, and $FAPbI_3$ perovskite films

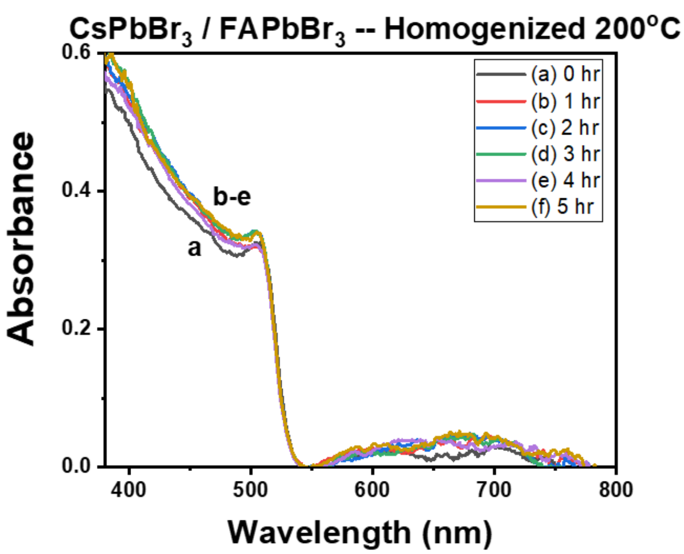
These results will allow us to continue research in the upcoming session. We will synthesize the thin films of $FAPbI_3$ perovskite and form a gradient structure with the formamidinium and cesium perovskites through cation exchange.There is one side with formamidinium and on the other side, there is cesium cations. Similarly to our experiments before, we expect there to be charge migration from the cesium to the formamidinium side of the film. Using absorbance and photoluminescence spectroscopy, we will track how the electron charges move through the gradient structure.



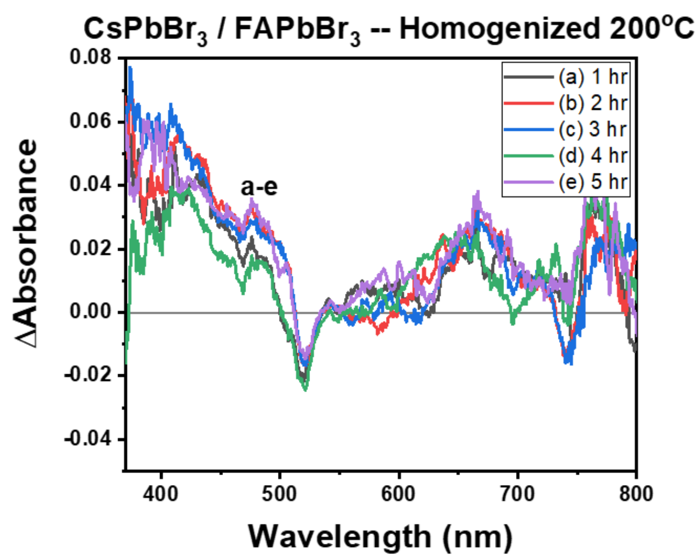
FAPbI3 / CsPbI3 -- Homogenized 150°C
Absorbance
Wavelength (nm)
(a) 0 hr
(b) 1 hr
(c) 2 hr
(d) 5 hr
(e) 10 hr
(f) 20 hr
(g) 40 hr
(h) 80 hr



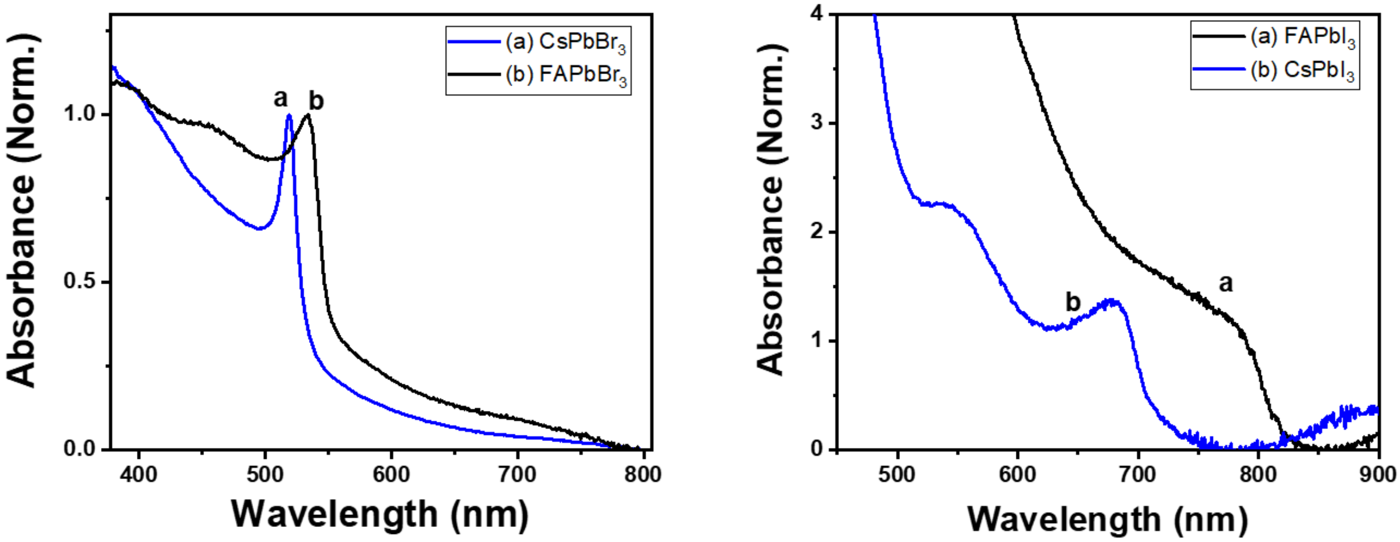
FAPbI3 / CsPbI3 -- Homogenized 150°C
ΔAbsorbance
Wavelength (nm)
(a) 1 hr
(b) 2 hr
(c) 5 hr
(d) 10 hr
(e) 20 hr
(f) 40 hr
(g) 70 hr



CsPbBr3 / FAPbBr3 -- Homogenized 200°C
Absorbance
Wavelength (nm)
(a) 0 hr
(b) 1 hr
(c) 2 hr
(d) 3 hr
(e) 4 hr
(f) 5 hr
b-e



CsPbBr3 / FAPbBr3 -- Homogenized 200°C
ΔAbsorbance
Wavelength (nm)
(a) 1 hr
(b) 2 hr
(c) 3 hr
(d) 4 hr
(e) 5 hr
a-e



Absorbance spectra of $CsPbBr_3$, $FAPbBr_3$, and $CsPbI_3$, $FAPbI_3$ perovskite films