CHANGES IN THE NSF PROJECT PROPOSAL

(Grammatical errors, Sentence formation/correction, Improvement in readability)

1.0 Elevator Pitch

- "The topic proposed herein is within the scope of the advanced materials program in NSF subtopic AM-X." to "The proposed topic falls within the scope of the advanced materials program under NSF subtopic AM-X."
- "The research for this project is focused on the development of thin film photovoltaics (PV) that can advance the solar and battery industry by lowering costs, emissions, and increasing energy independence within the US." to "This project focuses on developing thin film photovoltaics (PV) to enhance the solar and battery industry by reducing costs, emissions, and enhancing energy independence in the US."
- "However, these materials have several drawbacks, such as their high raw material and manufacturing cost, slow deposition rates, high labor and maintenance processing costs, and high emissions." to "Nevertheless, these materials possess various drawbacks including high raw material and manufacturing costs, slow deposition rates, high labor and maintenance processing costs, and elevated emissions."
- "To supplement these issues, AZO (Al-doped Zinc oxide) thin film deposition is being studied as one of the alternative materials." to "To address these challenges, research is underway on AZO (Al-doped Zinc oxide) thin film deposition as an alternative material."
- "Most techniques for PV thin films used today, commercially and academically, are deposited using plasma-enhanced atomic layer deposition (PEALD), chemical vapor deposition (CVD), sputtering, or reactive sputtering." to "The predominant techniques for PV thin films currently utilized in commercial and academic settings include plasma-enhanced atomic layer deposition (PEALD), chemical vapor deposition (CVD), sputtering, or reactive sputtering."
- "The commercial technique used for depositing AZO is PEALD and CVD." to "Commercially, AZO is deposited using PEALD and CVD techniques."
- "The proposed technique for depositing AZO is a hybrid technique, utilizing the chemical bath deposition (CBD) and spin coating methods." to "The

proposed method for AZO deposition involves a hybrid approach that combines chemical bath deposition (CBD) with spin coating methods."

- "This proposed research aligns with the NSF seedfund's merit criteria, encompassing intellectual merit and broader impacts." to "This research proposal aligns with the NSF seed fund's criteria focusing on intellectual merit and broader impacts."
- "The ultimate goal of this project is to begin at a technology readiness level (TRL) 2 and develop to TRL 4, with a validated benchtop article." to "The primary objective of this project is to start at technology readiness level (TRL) 2 and progress to TRL 4 while producing a validated benchtop article."

1.0 Commercial Opportunity

- "The need for cost-effective, efficient, and reliable PV technology has been growing rapidly over the past decade." to "There has been a rapid increase in demand for cost-effective, efficient, and reliable PV technology over the past decade."
- "Thin film photovoltaics are an economical and cost-effective solution." to "Thin film photovoltaics offer an economical and cost-effective solution."
- "Overall, the AZO market is expected to have substantial growth in the coming years." to "In general, substantial growth is anticipated in the AZO market in the upcoming years."
- "With technological advancements and the development of cost-effective manufacturing processes, the market is anticipated to grow at a CAGR of 13.4% from 2024 - 2031." to "Due to technological advancements and cost-effective manufacturing processes development, a Compound Annual Growth Rate (CAGR) of 13.4% is projected for the market from 2024 - 2031."
- "One of the key target markets for AZO research and technology is TCO applications; this market is expected to expand at a CAGR of 16.9% from 2022 – 2031." to "TCO applications represent one of the primary target markets for AZO research and technology; this sector is forecasted to grow at a CAGR of 16.9% from 2022 – 2031."
- "The expansion of solar energy in the United States is propelled by three key factors: economic dynamics of energy..." to "Solar energy expansion in the United States is driven by three main factors: economic energy dynamics..."

- "Due to this shift in green net-zero initiatives..." to "As a result of this shift towards green net-zero initiatives..."

3.0 Technical Solution Section (page 5):

- "Zinc oxide has a wide energy band gap, high optical transparency, and good stability, making it an attractive opportunity for PV applications" to "Zinc oxide's wide energy band gap, high optical transparency, and excellent stability position it as a compelling option for PV
- "In Swami et al., the research team uses ZnO and AZO as an electron transport layer in an inverted organic solar cell (IOSC) to analyzed and compare the differences with aluminum doping" to "Swami et al. utilized ZnO and AZO as an electron transport layer in an inverted organic solar cell (IOSC) to analyze and compare the effects of aluminum doping."
- "They found that when ZnO was doped with aluminum (Al) the PCE went from 9.3% to 10.5%, indicating the aluminum improves device performance" to "Their findings revealed that doping ZnO with aluminum (Al) increased the PCE from 9.3% to 10.5%, demonstrating improved device performance."
- "On a molecular scale, when Al is introduce to the crystallite structure the lattice constants and strain are decreased, directly influencing the surface morphology" to "Introducing Al at a molecular level alters the lattice constants and strain within the crystallite structure, directly impacting surface morphology."
- "There are many studies that show with an introduction of aluminum into the crystal lattice, around 3 – 5 wt%, the bandgap energy decreases from 3.37 eV to about 3.25 eV" to "Numerous studies demonstrate that introducing aluminum into the crystal lattice at approximately 3 – 5 wt% reduces the bandgap energy from 3.37 eV to around 3.25 eV."

Phase I Effort Section: (paragraph 2)

- "Rayn aims to continue its R&D efforts to create improvements in advanced solar energy technologies by reducing manufacturing costs" to "Rayn aims to advance solar energy technologies by reducing manufacturing costs through ongoing R&D efforts."
- "Rayn Innovations proposes starting the deposition of this material using a low-cost, low-temperature chemical deposition hybrid technique utilizing spin coating and CBD" to "Rayn Innovations proposes initiating material

deposition using a cost-effective, low-temperature chemical deposition hybrid technique that combines spin coating and CBD."

Challenges and Mitigation Section: (paragraph 3)

- "To overcome this challenge, ZnO must be doped to increase its carrier lifetime, i.e. aluminum doping" to "To address this challenge, ZnO needs doping for increased carrier lifetime, specifically through aluminum doping."
- "As a result, the cost of ZnO-based PV devices is still relatively high" to "Consequently, the cost of ZnO-based PV devices remains relatively high."

Page 8: Suggestions for Text Changes:

- "Rayn Innovations, an Arizona State University (ASU) startup" to "Rayn Innovations, a startup affiliated with Arizona State University (ASU)" for clarity.
- Replace "low-cost technology" with "cost-effective technology" to enhance.
- "typically less than five microns thick" to "usually thinner than five microns" for improved readability.
- "the adapted technology is derived from our original research" to "this adapted technology stems from our initial research" for conciseness.
- "the original technology uses spin-spray plating" to "initially, the technology employed spin-spray plating" for better flow.
- "From this research, two patents were issued" with "This research resulted in two patents being issued" for a more direct statement.
- "From this technology we intend to adapt the chemistry know-how" to "We aim to leverage the chemical expertise from this technology" for clarity.
- "The methodology implemented in the proposed project is robust" to "The methodology in the proposed project is robust and enhances worker safety."
- "The significance of this technology is the versatility and adaptation of the process" to "This technology's significance lies in its versatile and adaptable process."
- "AZO was chosen for various reasons including its multitude of applications" to "AZO was selected due to its wide range of applications."
- "Another reason is the bath chemistry, Rayn has a uniques chemistry that can chemically tune the material by altering various parameters." with

"Additionally, Rayn's unique bath chemistry allows for precise material tuning by adjusting different parameters."

- "The PI, Nicole Ray, has already proven this by depositing Ni-Zn-Co ferrite with unique properties; high Snoek’s product, uniform film, and a dense polycrystalline film." to "Nicole Ray, the PI, demonstrated this by depositing Ni-Zn-Co ferrite with distinctive properties like high Snoek’s product and uniform dense films."

Phase I Work Plan:

- "a the scientific method" to "using the scientific method."

5.3 commercial feasibility section:

- Confirm what unit (‘reem or ream’) is appropriate for the context.
- "It costs about a tenth of the unit price for the instrumentation" to "It costs about one-tenth the unit price of the instrumentation" for grammatical accuracy.
- In the sentence "All of these processes utilize low-cost equipment, abundant raw materials for the AZO bath solution, low-temperature, versatile parameters, and similar chemistry as in spin-spray plating for Ni-Zn-Co ferrite deposition," consider changing "low-temperature" to "low-temperature conditions" for better readability.