Proposal:

Biochar-impregnated self-floating system based on Omanis date palm fiber and Arabic gum for solar steam generation and environmental applications

Abstract

The development of a strong light absorption absorber with a facile preparation process are crucial for some photothermal conversion applications, such as solar steam generation, photothermal catalysis and detectors. A novel photoreceiver composed of Omanis Arabic gum embedded with biochar derived from Omanis date palm fiber for efficient steam production was investigated to measure the desalination efficiency under the illumination of one sun (1 kW m^{-2}). The density of localized hotspots on the surface of the photothermal system is enhanced by the incorporation of biochar based on palm wastes. Due to the numerous benefits of the fabricated device including superior performance, cost-effectiveness, all-weather use, and extensible fabrication, our integrated design holds promise for the fabrication of large-scale solar-powered steam for producing clean water. Moreover, the fabricated photothermal disk is expected to demonstrate a new strategy for solar energy harvesting, water treatment and other related fields.

Introduction and statement of the problem/project:

Freshwater scarcity is regarded as one of the most serious environmental dilemmas facing the world at the moment due to the rapid development of industry and the increase in the population [1, 2]. Significant worldwide issues like consumable clean water and clean energy can be resolved by making appropriate use of solar power and plentiful saline water resources [3]. The most plentiful and cleanest renewable natural resource on Earth is solar energy. Clean water can be generated by capturing solar energy using available water resources. The cost-effectiveness, environmental friendliness, and versatility of materials for solar photothermal energy conversion make them very desirable for a variety of applications, such as solar-powered desalination and residential water heating [4].

Numerous crucial operations can be powered by thermal energy including home heating, saline water desalination, sterilizing, distillation, and the production of electricity. Desalinating seawater is a viable substitute to mitigate water shortages. By effectively utilizing renewable solar energy, the photothermal evaporation (PE) method exhibits notable advantages in both energy savings and environmental impact reduction when compared to several traditional processes like multistage flash distillation and reverse osmosis filtration, which might necessitate a relatively high energy supply with additional infrastructure [5, 6]. Solar-driven interfacial evaporation has become a novel approach to evaporation design in recent years [7, 8]. It localizes solar heating at the air-water interface instead of heating the bulk liquid. In interface solar-thermal water evaporation, the water yield and its suitability for real-world applications are primarily determined by the water evaporation rate and solar-thermal conversion efficiency. Considerable efforts have gone into improving them by reducing heat loss and increasing light absorption [2]. High optical concentrations (10−1000x) are needed in traditional concentrated solar power steam generating systems in order to produce hot steam. In addition to raising the cost of the evaporation systems to a significant level, which would prevent solar-thermal systems from being installed in underdeveloped areas, the costly optical concentrators reduce the system's overall energy conversion efficiency because of greater thermal losses from the heated solar recipient surfaces [7]. Three significant concepts for creating high-performance interfacial solar steam generation (ISSG) have been identified by earlier research: (1) thermal localization at the evaporative zone to reduce heat loss; (2) maximizing the conversion of solar energy into heat by using photothermal materials with broadband absorption and (3) maintaining constant evaporation by providing enough water through capillary action of hydrophilic and porous matrix [8]. The photothermal material is the focal point of the ISSG system, and it consists primarily of metallic compounds with plasmonic effectiveness, semiconductors with nonradiative relaxation, and carbon-based materials with molecular thermal vibration principle [9].

Most ISSG systems are based on carbonaceous materials like graphene oxide (GO), graphene acid (GA), hollow carbon spheres and carbon nanotubes (CNTs) due to their high ability to absorb sunlight [10-12]. Unfortunately, the synthesis of these materials often involves several stages and high temperatures, which raises inquiries over their affordability which is crucial for solar thermal water treatment [13]. These factors highlight the necessity for photothermal materials that are affordable, stable, scalable, and extremely effective.

Usually, the majority of biomass materials involve sophisticated mesostructures that facilitate the movement of nourishment and water along the growth direction during photosynthesis [14]. Biomass materials including wood, maize straw, and rice straw can serve as water paths for high-efficiency SSG devices due to their unique topologies. Monolithic and single-layered ISSG evaporators can be generated from the simple carbonization of some biomass such as carbonized wood, mushrooms corn straw and rice husk [15-17]. Carbon-based materials emphasize excellent heat management, transportation of water, and light absorption due to their rough, black surfaces and porosity. Omanis palm fiber may regarded as two sides of coin that can be disposed causing environmental pollution or used as valuable resources [18]. The benefits of resource conservation and environmental friendliness are particularly applicable to wilderness survival, where access to clean water is a critical necessity.

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Literature review

To demonstrate the expected superiority of our absorber, the previous work in the field of light absorbers such as porous materials, nanomaterials, and films have been summarized in the following table.

Evaporator	Evaporation rate (kg m^{-2} h^{-1})	Efficiency (%)	Reference
Ag@TiO_2 NPs	1.2	79	[1]
BT nanocages (210 °C)	1.13	70.9	[2]
BTCC nanocomposites	1.515	94	[3]
GO/PU foam	0.568	81.0	[4]
E-PNS_{BT-8}	1.5297	90.0	[5]
Ti_2O_3 NP-loaded cellulose	1.32	92.5	[6]
BNC/BT PTF_b	1.71	84.3	[7]
BTW nanocomposites	2.04	90.06	[8]
CDs/Black TNA@Ti	1.762	55.3	[9]

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Objectives

1. Preparation of biochar-based Omanis palm fiber.
2. Fabrication of black disk from Omanis Arabic gum and biochar.
3. Test the prepared disk for sweater desalination under real sun.
4. Investigate the salt rejection property of fabricated photothermal ISSG.

Benefits to Oman

1. Preparation of valuable biochar from Omanis palm fiber.
2. Conversion of biomass to valuable compounds: waste to wealth.
3. Saline water desalination from the Gulf of Oman.
4. Raising the attention to environmental sustainability.
5. Advanced scientific research schools.

Outline of proposed activities/Research Methodology:

The research will go through the following steps:
1. Collecting the Omanis palm fiber, cutting, drying and grinding.
2. Preparation of biochar by pyrolysis of palm fiber under nitrogen flow.
3. Fabrication of photothermal disk by mixing the derived biochar with Omanis Arabic gum.
4. Structure elucidation of the prepared samples by different analysis techniques.
5. Test the seawater desalination performance of the prepared ISSG disk.

Work plan

Steps	Description	Time (month)
1	Data collection and literature review	3
2	Collection and preparation of ground palm fiber	2
3	Synthesis of biochar and photothermal device	4
4	Characterization of the synthesized materials	5
5	Investigate the performance of the prepared ISSGs for seawater desalination	6
6	Finishing of article related to the previous work	4

Budget:

Budget Categories

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Expense Category	Budget Caps	Year 1 (OMR)	Year 2 (OMR)	Total (OMR)
Materials and Supplies	10,000.00	3,000.00 8/∞	3,500.00 8/∞	6,500.00 8/∞
Travel Expenses International Conference	2,000.00	0.00 0/∞	2,000.00 8/∞	2,000.00 8/∞
Data Collection/ Analysis	2,000.00	1,000.00 8/∞	1,000.00 8/∞	2,000.00 8/∞
Equipment and Facilities	5,000.00	2,000.00 8/∞	1,000.00 8/∞	3,000.00 8/∞
Research Assistant/ Technician Post Doc	5,000.00	2,700.00 8/∞	0.00 0/∞	2,700.00 8/∞
Research Assistant/ Technician Research Assistants (Post Graduate)	5,000.00	1,750.00 8/∞	0.00 0/∞	1,750.00

Devices list

1- **Solar Simulator – SciSun**:>>>>>>>>>>>>>>2000 RO
Specifications:
Model: Solar Simulator - SciSun
Company: Sciencetech Inc.
Type: Lamps
Spectral Output Range (nm): 350 - 2500
Power Output Range (mW): 100 - 200
Test Plane Area (mm): 50 × 50

Variable Attenuator: Adjust from 0.1-2 sun
Lamp Wattage (W): 150 or 300
Irradiance Intensity: 1 Sun or 2 Sun
Working Distance (mm): 380
Lamp Type: Xenon (Ozone free)

2- Thermal IR Camera:>>>>>>>>>>>>>>>200 RO
Specifications:
Main function:
2-megapixel white lens
2.4 TFT LCD Display
Temperature testing range: -10°C ~ 400°C
32×32-pixel resolution, 33° Field of View
Merging visible and infrared image display
Chargeable Li-ion battery (charge by micro-USB interface)

3- Peristaltic pump:>>>>>>>>>>>>>>>300 RO

Is this project going ton result in a patent?

Yes

This research is expected to be published as a patent because it is the first time a photothermal disk consisting of biochar derived from palm wastes is embedded with Omanis Arabic gum used for solar steam generation and seawater desalination. Furthermore, the incorporation of Arabic gum is anticipated to show an excellent ability to reject salt from the surface of photothermal.

<u>Scientific academic and Innovation</u>

We foresee that the suggested study will significantly improve the field of water in general. Out of all the freshwater storage systems currently available interfacial solar steam generation systems (ISSGs) remain one of the most coveted seawater desalination systems. Due to the high demand for clean water, the environment is severely impacted, due to the traditional methods depending on the fossil fuel that release highly toxic compounds. To overcome such issues, this proposal would employ highly efficient and sustainable materials based on biochar derived wastes as photothermal devices.

If implemented successfully, the innovative light absorber materials will make it possible to fabricate excellent materials at a reasonable cost for use in solar steam generation devices. Particularly, the development of practical large-scale ISSGs would have profound social and economic effects on developed nations with very limited energy resources. By offering a way to produce clean water and make it accessible for everyday requirements, ISSGs may be utilized intermittent renewable sources like solar power. In terms of technical performance metrics, at the end of the designated study period, we hope to have met the following specifications:

1. Designing novel materials with good stability and durability for solar steam generation.
2. Attain high evaporation flux more than 1.5 kg m^{-2} h^{-1}.
3. Build photothermal system with the aforementioned specs and good salt rejection property.

Institutional Collaboration

-Environment Authority, Oman

- Damnhour University, Eygpt