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Application of 3D Printing in Solar Desalination - a Brief Review

K Venkateshwaran, Ajay Kumar Kaviti and V.V.D Sahithi

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Application of 3D printing in solar desalination - A brief review

K.Venkateshwaran [a,b] , Ajay Kumar Kaviti [a,b] , VVD.Sahithi [b]

a centre for solar energy materials, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, 500090, India.

b Department of Mechanical engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, 500090, India.

Abstract:

Population growth is increasing day-by-day; hence humanity will face issue with the drinking water. To overcome this issue, there is a technique called solar desalination which utilizes solar energy to eliminate salt from saline or brackish water and produce pure water. From several decades, there are many structures like nanoparticles, nanowires, nanotubes and nanoarrays that are used in solar desalination. But recently many researchers are showing particular interest in utilizing 3D printing technology in order to develop structure for solar desalination. 3D printing technique is a cost-effective method which can build the models in less duration of time and also the 3D printed material has a tendency to break bulk water cap to achieve high evaporation rate under 1 sun irradiation. In solar desalination, 3D printing is used to create evaporator, based on the design aspect in order to convert water into steam. This review article is mainly focused on different 3D printing techniques used to create various structures of evaporator for solar desalination. Various properties such as high evaporation rate, high efficiency and water quantity obtained from those structures is also discussed in this review.

Keywords: Catiav5, 3D printing technique, structure formation, solar energy, portable solar still.

1. Introduction

Water scarcity is a major issue that need to be solved immediately. In the summer season water is very precious thing where we can't find the water, in the lakes, rivers and ponds. So this issue is going on increasing day by day. So there is method called desalination technique which is used to develop pure water from salt water using solar energy. So it is named as solar desalination. Hence solar desalination is a type of cost-effective method which takes salt water as inlet and gives pure water as outlet. Various materials have been used for solar desalination.[1]Solar or thermal desalination is an oldest method has been around thousands of years ago. In the principle of solar desalination water is boiled, steam is collected leaving the salt behind. The usage of 3D printing technique here is creating an evaporator which has self-floating ability in water application.[2]The evaporator itself absorb solar radiation and produces water by eliminating the salt. The vapour droplets are collected in the pipe and transferred to a beaker which is called as pure water. Solar still is an airtight design which is constructed by wood with a rectangular cross-section with a top cover of inclined transparent glass for collecting water droplets. [3]Here a 3D printed evaporator is placed inside the still which has thermal absorption capacity for converting the water to vapour. Hence the setup is a cost effective method to produce pure water for drinking purpose. The side walls of the still are painted with black to increase heat absorption. A half pipe was placed below the glass so

that the vapour water droplets are flowed through the pipe. The purified water from the output pipe is collected in a bottle or beaker.[4]There are three environmental factors effecting performance the solar still which we can't control. The first factor is sunlight if we get enough sunlight, evaporator produce proper thermal absorption and get proper humidity and wind. The second factor is design of the device how much light received, how much deep the water is, material to produce condensation and how the heat is transferred to bulk water. The third factor is the salt accumulation which blocks the holes of the evaporator were output quantity of water produced is less due to blockage of holes.

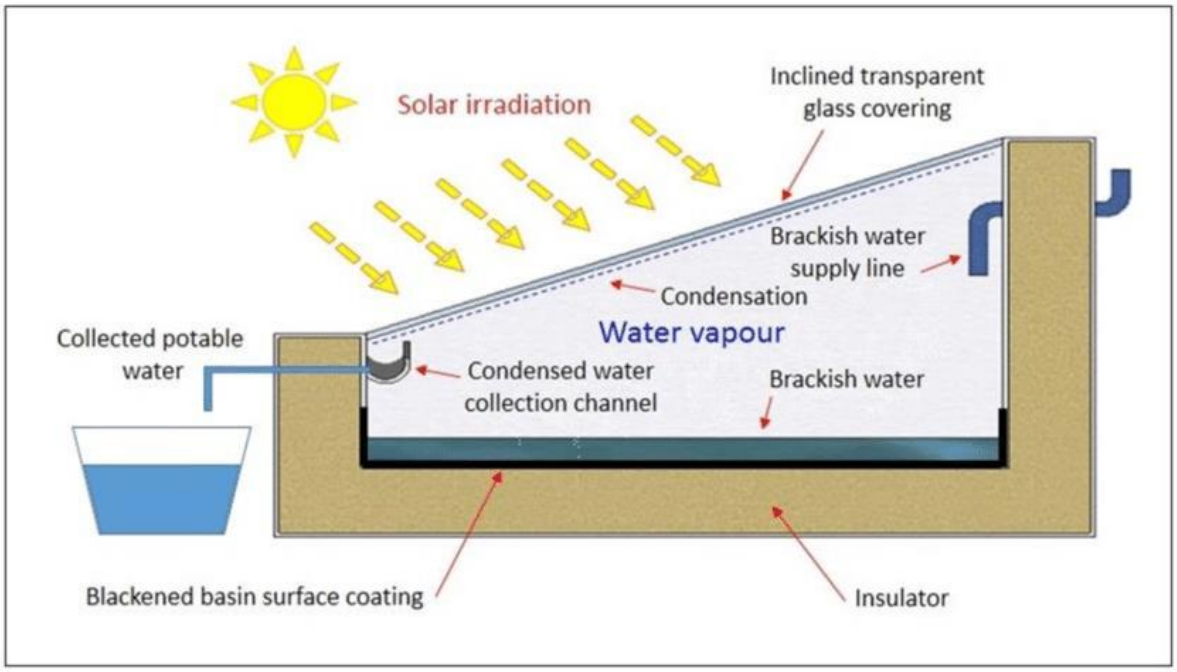


Fig.1 Schematic diagram of solar still[5]

The working principle of solar desalination is to eliminate salt water and produce pure water by using 3D printing absorber or evaporator. It must be black in colour for thermal absorption. It also tends to float in water and have an absorbing capability. Salt water is taken as inlet in a still and the evaporator is placed in the still for experimentation. By using solar energy and capillary force the evaporator absorb water, using heat energy water is converted to vapour leaving the salt in the still. The vapour is in form of water droplets collected in the pipe and formed as fresh water for the drinking purpose.[6]

2. 3D Printing Technique

This is most effective method used in solar desalination. The 3D printing structure is developed using design software and printed in 3D printer machine. Complex design is also created within less time. The techniques used in the literature review are Vat photopolymerization, Robot 3D printing technique, Stereolithography, Selective laser sintering etc used for making 3D printed evaporators.3D structure is created as water absorber which used to absorb more salt water and give more pure water for drinking purposes. To intake more water the model must have larger surface area and angle of contact to absorb more water. If the evaporator have achieved these above features, then the evaporator is placed in the still for obtaining drinking water. The

evaporator must undergo self-floating ability in the water application.[7]

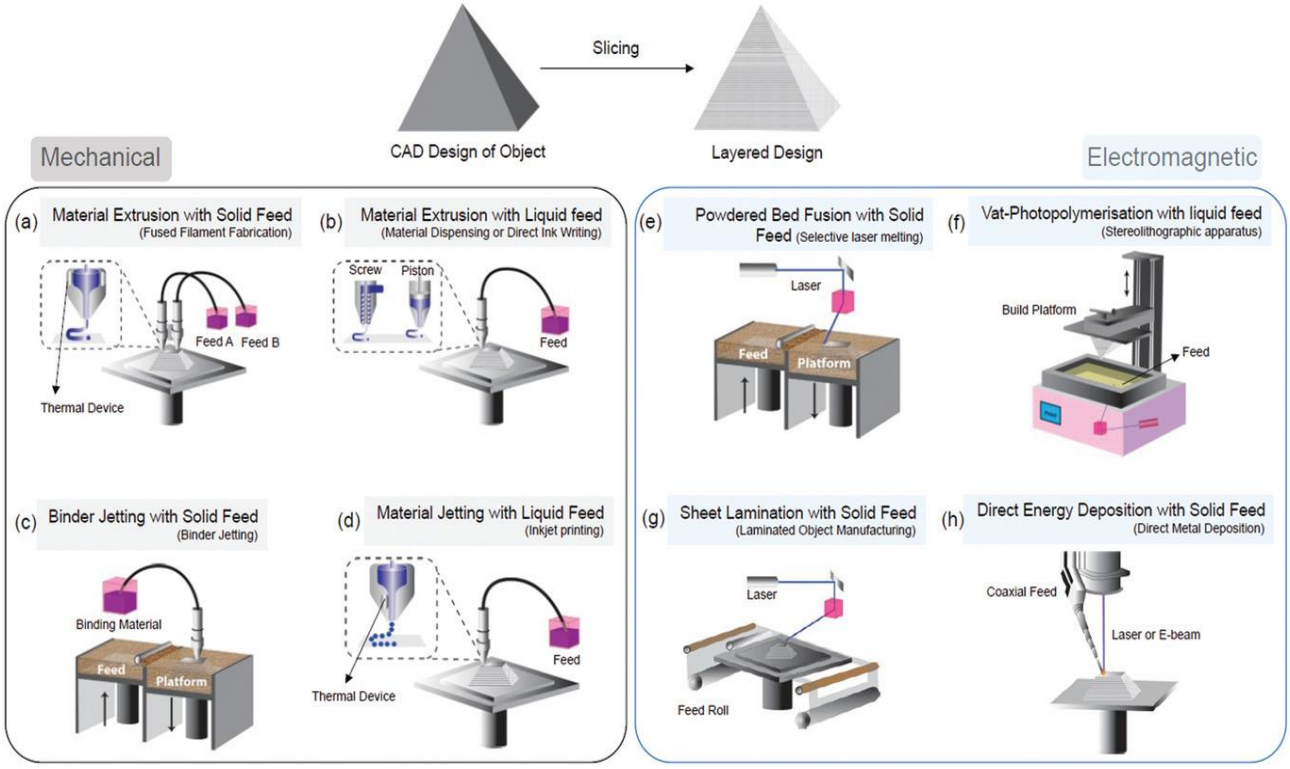


Fig.2 Schematic representation of 2 different 3D printing techniques[8]

3. Application of 3D printing in solar desalination

Fabrication of 3D-Printed, All-in-One Evaporator[9]

The 3D printed technique used to create an All-in-One evaporator is a benchtop robot which is operated by program code. Materials used for creating evaporator is CNT/Go and GO/NFC which comes under carbon material. They are in ink type which is loaded in syringe with stainless steel nozzle for printing it in a wafer type flat ceramic. After the printing it is transferred to freeze dispenser to remove the solvent. The sample are annealed in argon atmosphere of about 140 degrees to stabilize the structure. After printing the film, mesh and wall they are overlapped each other because three of them has different functions. Film act as irradiation absorption, GO/NFC as water transport and GO/NFC wall as water uptake. The technique used is layer by layer 3D printing technique which is controlled by program code and therefore creating a concave structure. Hence it has a weight of 79.2 mg which is lighter in weight has an ability to float in water. Here the comparison is done for efficiency, solar absorption and evaporation rate. By using All-in-One evaporator, they achieved high efficiency of 85.6%, >97 absorption and evaporation rate is grater then pure water. By using All-in-One evaporator, they achieved high efficiency in solar steam generation under 1 sun illumination.

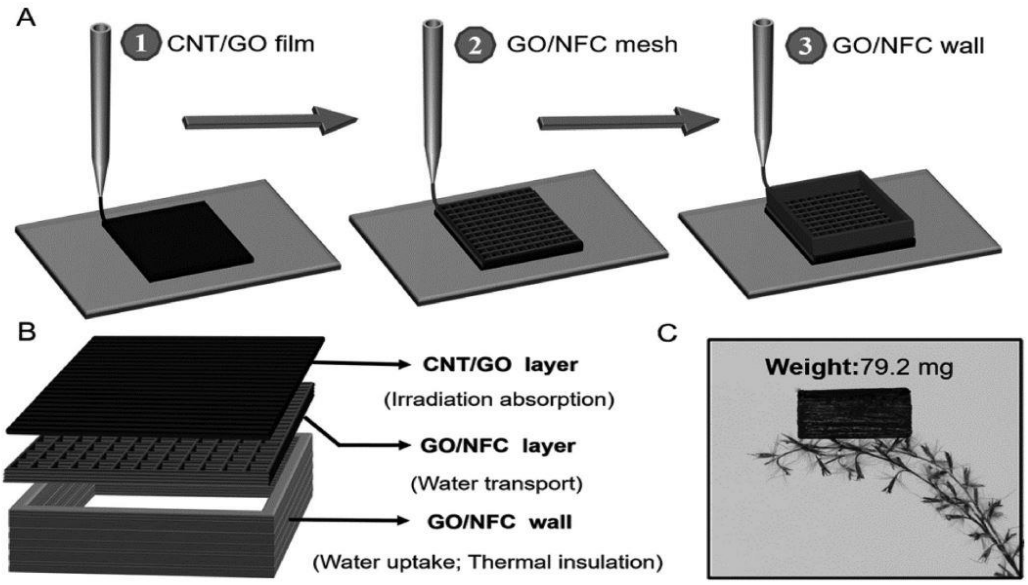


Fig.3 a)CNT/GO for heat absorption b)GO/NFC for water transport c)GO/NFC water uptake

Interfacial solar steam generation (ISSG)[10]

The printing technique stereolithography was used to create an 3DP ISSG using photo resin 9400 as material matrix. The resin has properties of low thermal conductivity, less cost and less weight. The structure formed is micro porous structure. Different kinds of shapes like triangle, circle, square and hexagon were developed to determine capillary pumping of water. Graphene powder is widely used as broadband and effective absorber of the energy of the entire solar spectrum. Hence for the created structures graphene ink are coated for heat absorption. The device has collegial features including CWT capillary facilitated water transport, thermal insulation which has high solar steam generation and hydrophobic layer. The rapid capillary pumping of water with vertical microchannels removes salt accumulation, which equally balances water transport and increase solar evaporation. The device also achieves an ultrafast solar evaporation rate under 1 sun irradiation.

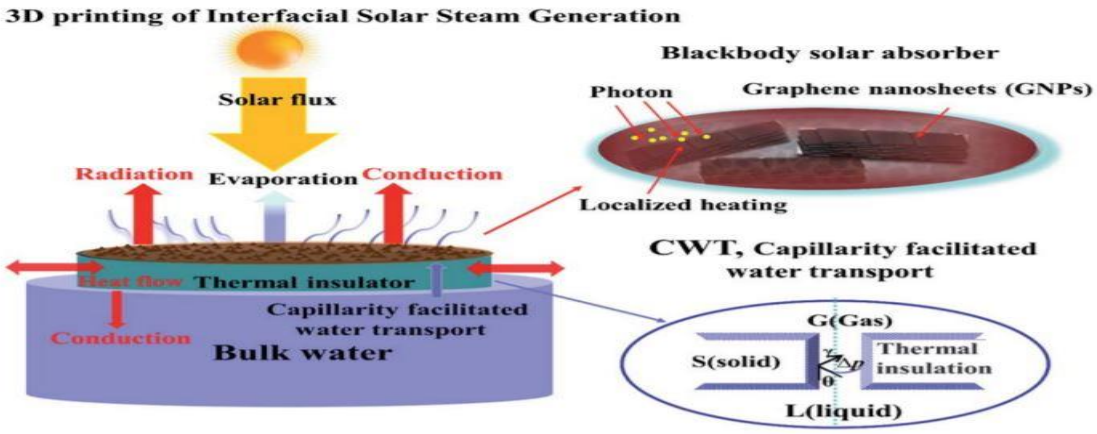


Fig.3.1 Schematic diagram of 3D printed interfacial solar steam generation with Capillary facilitated water transport

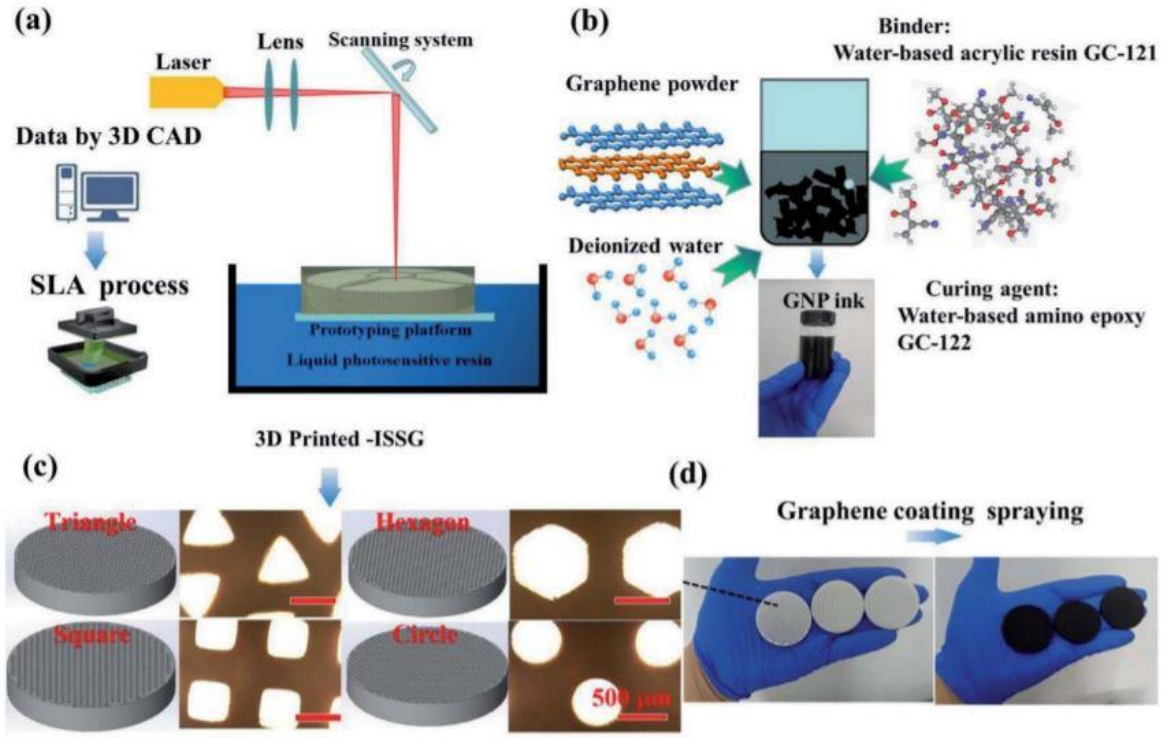


Fig.3.2 a)3D printing technique b)Composite resin c)Different shapes of 3D printed evaporators d)Coating for 3D printed evaporators

Highly efficient 3-dimensional solar evaporator[11]

Design was created for solar evaporator for super liquid transport of the asymmetric capillary ratchet of the bird beak and the pitcher plant peristome surface. The 3-dimensional structure formed is asymmetric grooves and microcavity array. The printing technique used for creating the structure is DLP which is called as digital light processing comes under the vat photopolymerization by forming a micropore surface. The resin was prepared by mixing the two materials carbon nanotubes and sodium citrate. CNT are chosen as photothermal material and sodium citrate are chosen for surface distributor pore producer in 3D evaporator because sodium citrate not able to flow along with the refilling resin during the continuous printing process, as the slicing thickness is much smaller than the particle dimension.

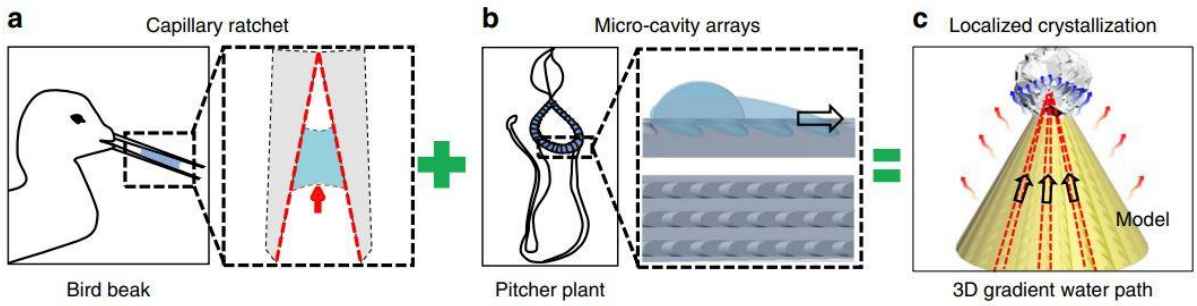


Fig.3.3 a) Bird beak capillary rachet for water uptake b) Microcavity array c) 3D printed evaporator

Biomimetic Bridge-Arch Solar Evaporator[12]

In this home-made DLP(Digital light processing) is the 3D printing technique which comes under Vat Photopolymerization. Materials used for the printing is a composite resin mixture of two resin which are acrylic ester and carbon fibers. Hence structure developed by them is an array of grooves and microcavity. Here they used four angles of 45°,90°,135°,180°. But 180° is the most used here because it has larger area and more angle when compared to the three. So, 180° is selected as evaporator and printed in 3D printing machine. The created absorber must have a self-floating tendency in the water which is placed in desalination still. By using solar energy salt water is poured in the still the bridge is pasted with PS foam for support in the still which is not drown, using solar energy heat is produced and steam is generated in the still. Stem droplet water is collected in the beaker. The desalinated water certified by WHO standard which meets the drinking requirement and can also be used for crop growth.

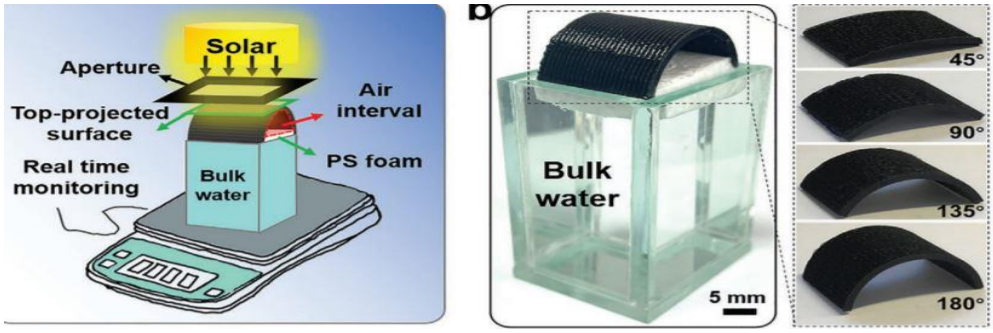


Fig.3.4 a)Schematic diagram of solar driven water evaporation b)Experimental setup for solar desalination c)Images of bridge arch evaporator with different angles

3D printed evaporator with double layer photo absorber[13]

In this the author have designed a double layer photo absorber for comparing which have achieved better results. They created an evaporator with plane surface and 3D cone one. For that author has used a 3D printing technique for creating a double layer photo absorber one has single reflection P-S and other has multiple reflection V-85. P-S has a planar surface which has lower surface area and lower angle of contact whereas V-85 has larger surface area and angle of contact which is used an evaporator in the solar still. Using solar energy we use both the absorber and tested with experimentation. Results are good for V-85 when compared to P-S. V-85 has a tendency to reutilize solar energy using multiple reflections. Hence the results are obtained for the absorber having 89% of efficiency and 1.60 kg m–2 h–1 of evaporation rate.

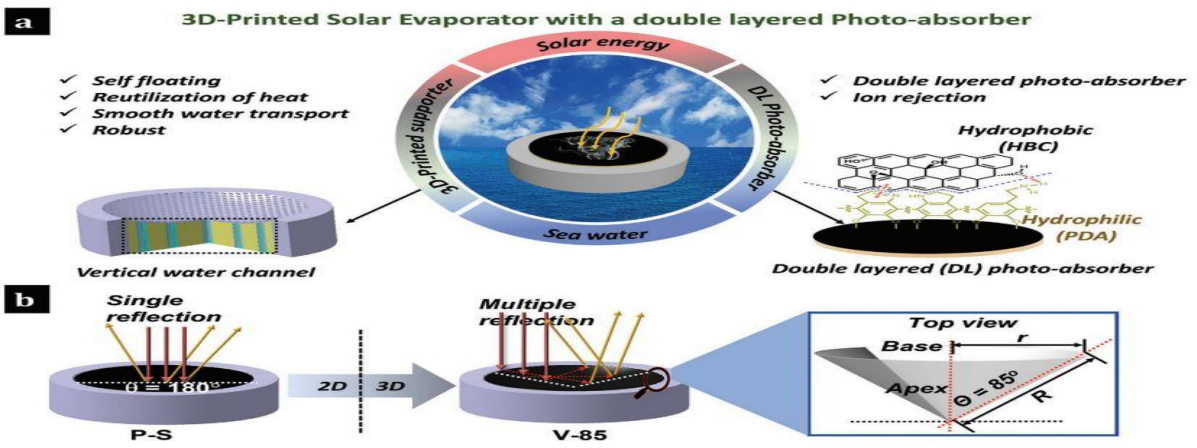
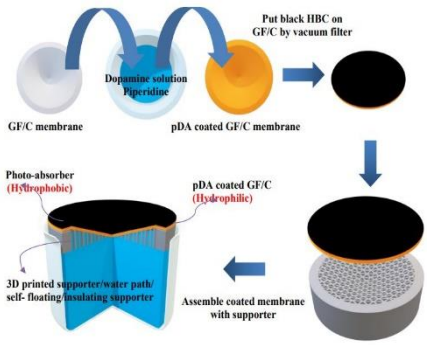


Fig.3.5 a)Double layer photo-absorber b)Single reflection P-S c)Multiple reflection V-85

Building and fabrication of 3D Solar steam generation device[14]

3D printing technique used here is DLP method which comes under the vat photopolymerization to create an 3D SSG device. It has a microporous triangular structure for water uptake. After creating the 3D absorber it does not have self-floating ability. So six holes has been placed on the side edge and they are closed with resin now the absorber has a tendency to float in water related application. For absorbing the thermal energy they designed photo absorber pda coated GF/C with HBC and pristine coated GF/C with HBC. The both absorbers are placed in water but pristine in water releases some chips in the form of powder dissolved in water which does not suit for water related application. Hence Pda coated GF/C membrane with HBC is suitable for water application. The device shows an excellent solar to vapor conversion efficiency of 89% under 1 sun irradiation of 1 kW/m2.



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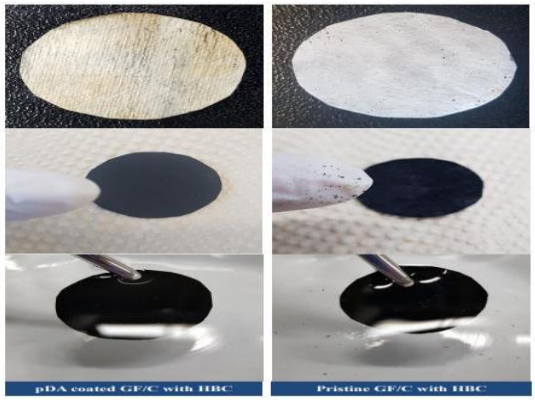

9.1

Fig.3.6 Schematic model of 3D printed solar steam generation device Fig.9.1 a)PDA coated GF/C membrane with HBC b)Pristine coated GF/C membrane with

Fabrication of 3D-Printed Ceramic Structures for Portable Solar Desalination Devices[15]

The ceramic device consisting of solar absorber, thermal insulator and water transported is developed using the robocasting 3D printing technique. Hence it can desalinate saline water to fresh water without adding additional parts. The structure developed is microporous to absorb more water and give best results in evaporation rate and efficiency. The material used for 3D printing is graphene and silica which is made in the form of ceramic. It is a bifunctional solar absorber which has water transporter, hydrophilic solar absorber and thermal insulator. It has a collection hood to absorb and intake water. integrated solar absorber and wick absorb thermal energy produced from the sun generated heat inside the hood evaporates salt water and produce fresh water. ceramic floater is used to hold the hood and integrated solar absorber and wick and collects pure water.

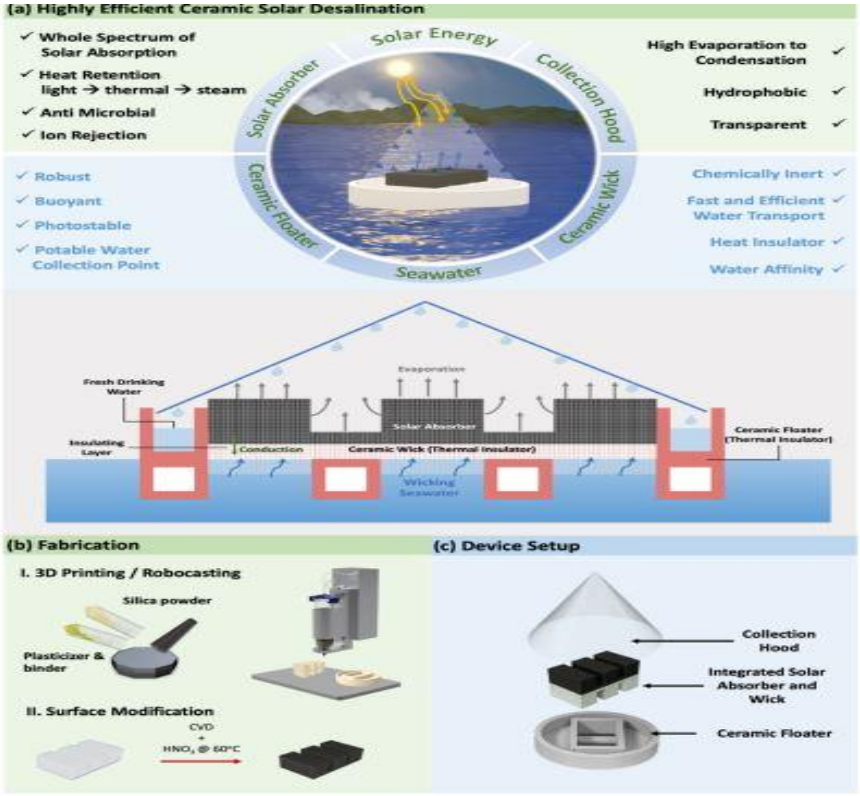

Fig.3.7 Highly efficient ceramic solar desalination device. (a) Requirements of the ceramic solar desalination device and 2D schematic diagram depicting how it works. (b) Method of fabrication through robocasting of the ceramic solar desalination device and surface modification to fabricate the solar absorber. (c) 3D drawing of the full setup.

4. Conclusion

The water absorbed by the 3D printed evaporators achieves evaporation rate using the solar energy and converts salt or brackish water to fresh water by using 3D printing technique. The evaporator material must be in black colour to absorb more solar energy to evaporate more water. 3D printed components can obtain better results in evaporation rate and have higher efficiency. The method called solar desalination is a cost effective process to develop pure water using 3D printing technique.

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