Harnessing Bioengineered Solar Absorbers for Eco-Friendly Thermal Solutions

(A case-study of Cu exposed to *Allium sativum*)

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Agenda

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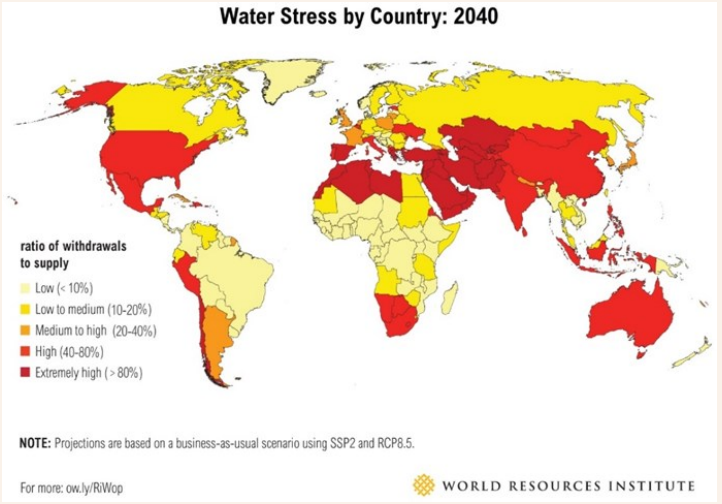
Aim

To employ non-toxic, environmentally friendly methods for the development of a solar absorber surface that can be used for thermal applications, such as the desalination of seawater.

Introduction

- The escalating demand for freshwater has spurred the development of novel methods for acquiring this vital resource.

- While an impressive 71% of Earth's surface is covered by water, a mere 3% qualifies as freshwater, and only 1.2% is readily available for human consumption. The remainder is locked in glaciers [1].

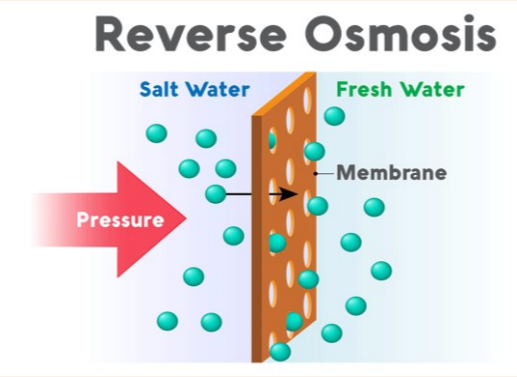


Source: https://www.wri.org/insights/ranking-worlds-most-water-stressed-countries-2040, *Accessed: 02 October 2024*

[1] Water Science School (U.S. Department of the Interior), 2019. The distribution of water on, in, and above the Earth | U.S. Geological Survey. *USGS*, [online] Available at: https://www.usgs.gov/media/images/distribution-water-and-above-earth#:~:text=About%2071%20percent%20of%20the,in%20you%20and%20your%20dog [Accessed 13 Jun. 2024].

Introduction

- Seawater desalination is a potential solution for the demand for freshwater. However, the methods currently employed demand significant amounts of energy which, consequently, have a negative environmental impact.
- To address the highlighted challenges, this project aims to study, experiment, implement and introduce a novel means of using solar energy (in combination with a uniquely bio engineered material) for distilling saltwater.
- This project aims to exploit the superior solar (energy) absorption properties of a bio-engineered, sativum-mediated copper surface.



Source: https://cdn.shopify.com/s/files/1/2723/8896/files/FWS_Blog_Reverse_Osmosis.gif?v=1561665570 , *Accessed: 08 October 2024*

Literature Review

- Copper Sulfide (CuS) surfaces have been incorporated into several thermal applications due to their high thermal conductivity and desirable optical properties.
- CuS has been employed in solar energy conversion, particularly in band gap engineering for solar stills, improving efficiency [2].
- Additionally, CuS composites have been employed for heat storage and photothermal conversion, leveraging their ability to store and convert thermal energy efficiently [3].

[2] Fernandes, J. *et al.* (2024) 'Band gap engineering of g-C3N4/CuS and its application in Solar Still,' *Chemical Physics Impact*, 9, p. 100684. https://doi.org/10.1016/j.chphi.2024.100684.

[3] Yan, T. *et al.* (2024) 'Preparation and characteristic of palmitic acid/flower-shaped CuS composite phase change material for effective heat storage and photothermal conversion,' *Materials Today Sustainability*, 26, p. 100768. https://doi.org/10.1016/j.mtsust.2024.100768.

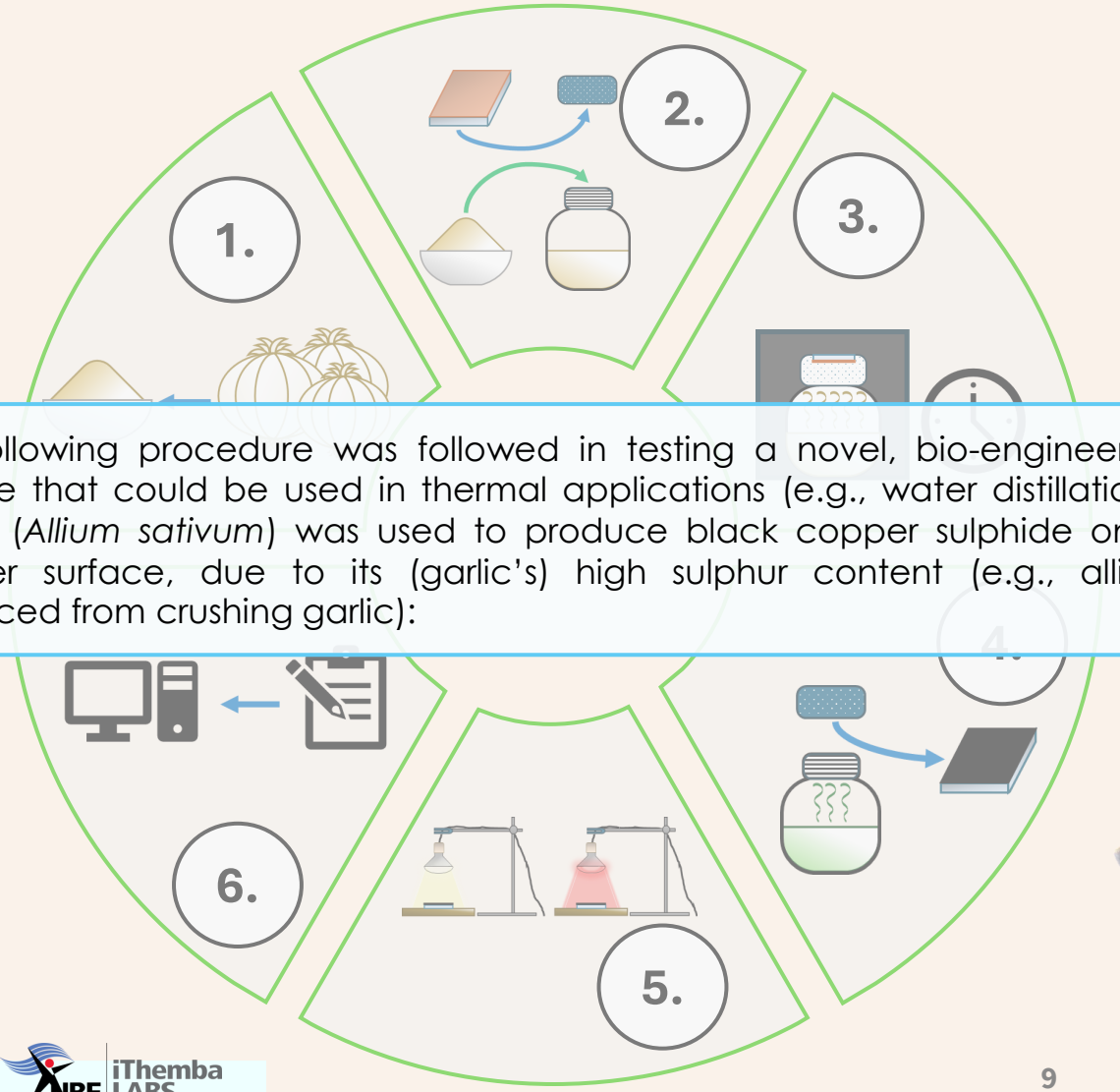
Literature Review

- In addition to CuS, bioengineered surfaces are gaining traction in thermal applications. A study by Yang et al. [4] delineated four variants of biochar-based solar absorbers, fashioned from biomass extracted from E. prolifera.

- The devised design integrated the utilization of E. prolifera biomass, which is abundant in numerous coastal regions. The hierarchically porous and tubular nanostructures inherent to the carbonized E. prolifera served as effective “catchers” of solar energy. This method serves as a useful example for employing bioengineering processes in sustainable solar-thermal applications.

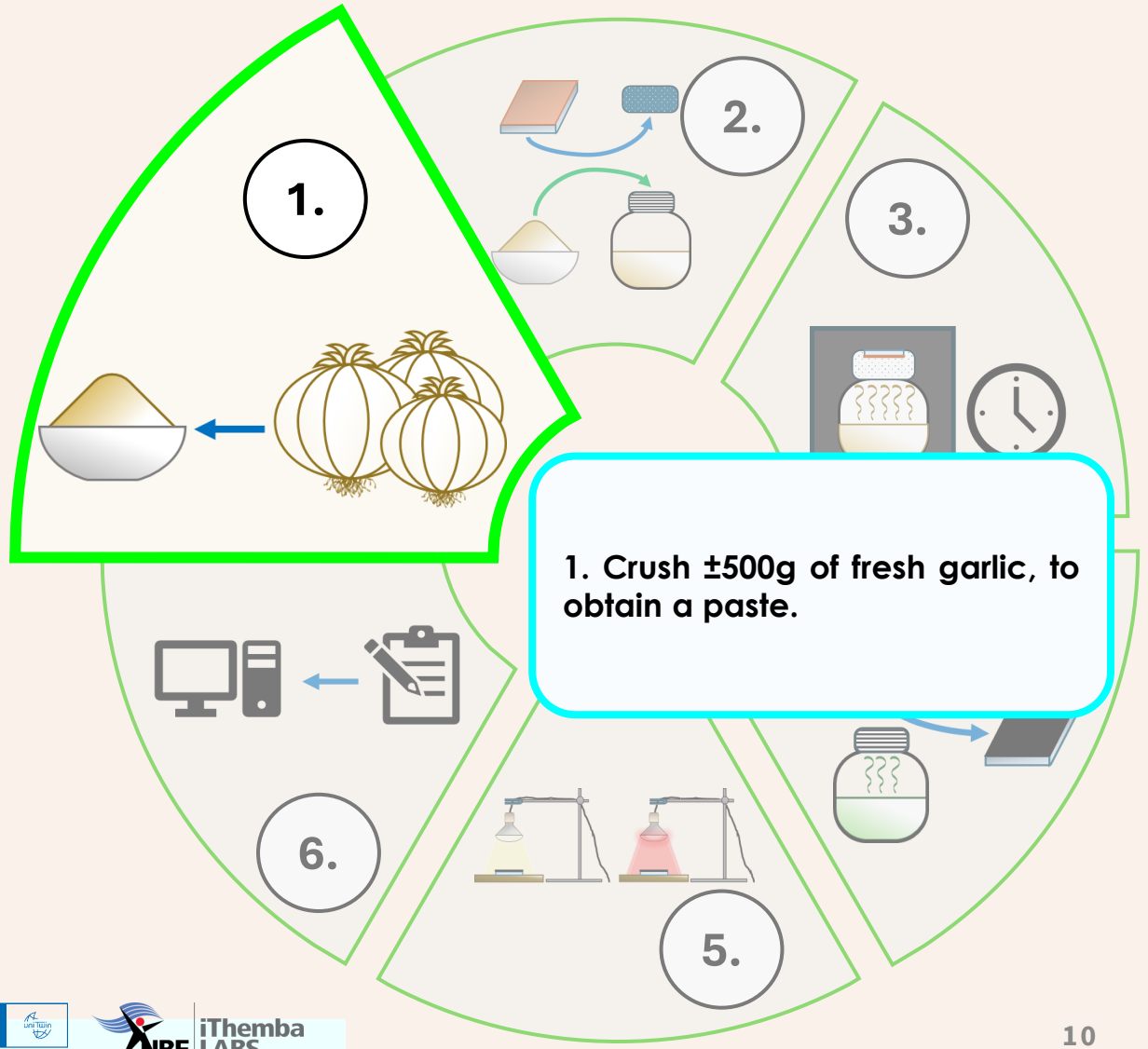
[4] Yang, L. *et al.* (2019) ‘Sustainable Biochar-Based solar absorbers for High-Performance Solar-Driven steam generation and water purification,’ *ACS Sustainable Chemistry & Engineering*, 7(23), pp. 19311–19320. https://doi.org/10.1021/acssuschemeng.9b06169.

Experimental Procedure



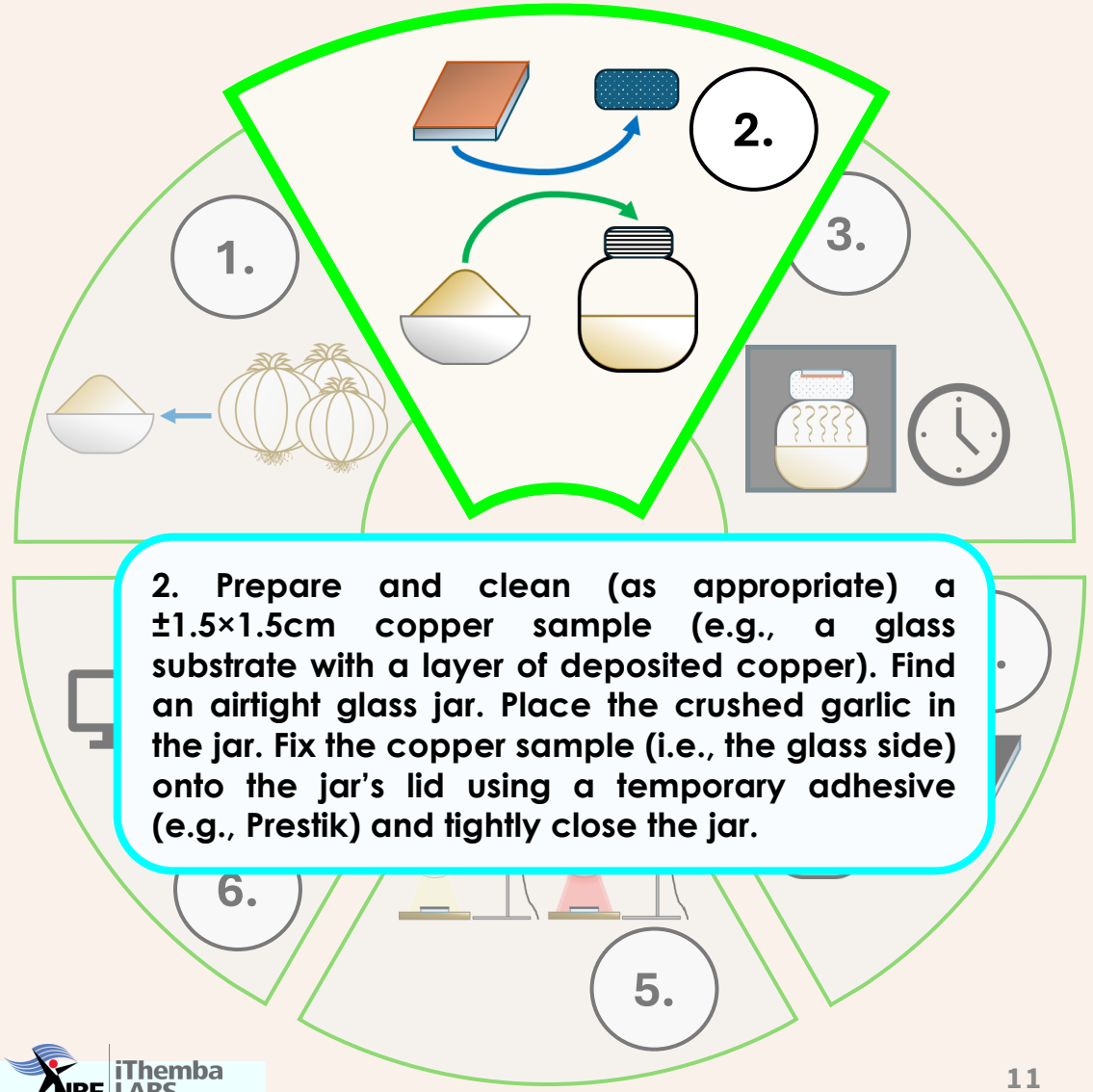
The following procedure was followed in testing a novel, bio-engineered surface that could be used in thermal applications (e.g., water distillation). Garlic (*Allium sativum*) was used to produce black copper sulphide on a copper surface, due to its (garlic's) high sulphur content (e.g., allicin produced from crushing garlic):

Experimental Procedure



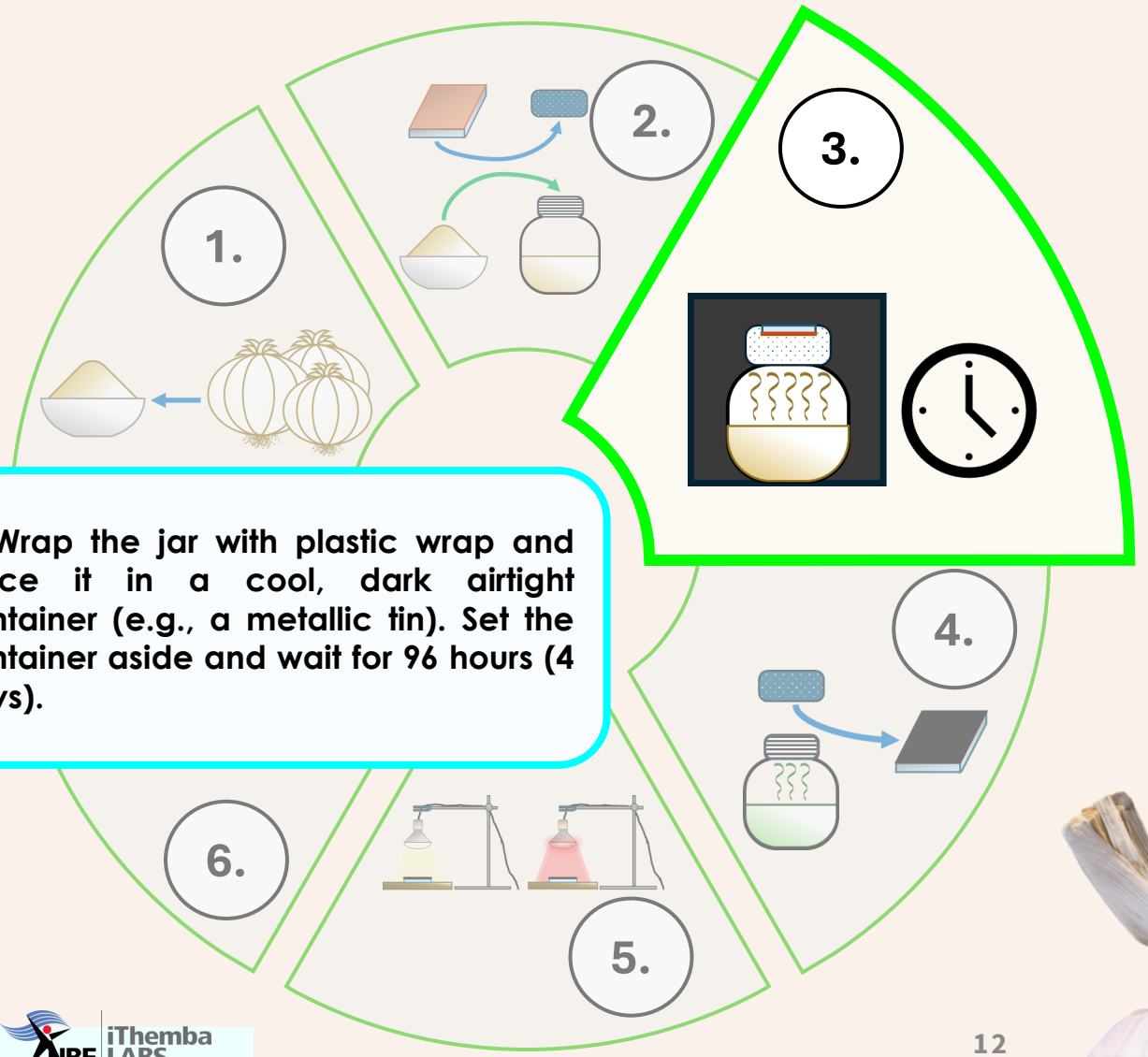
1. Crush ±500g of fresh garlic, to obtain a paste.

Experimental Procedure



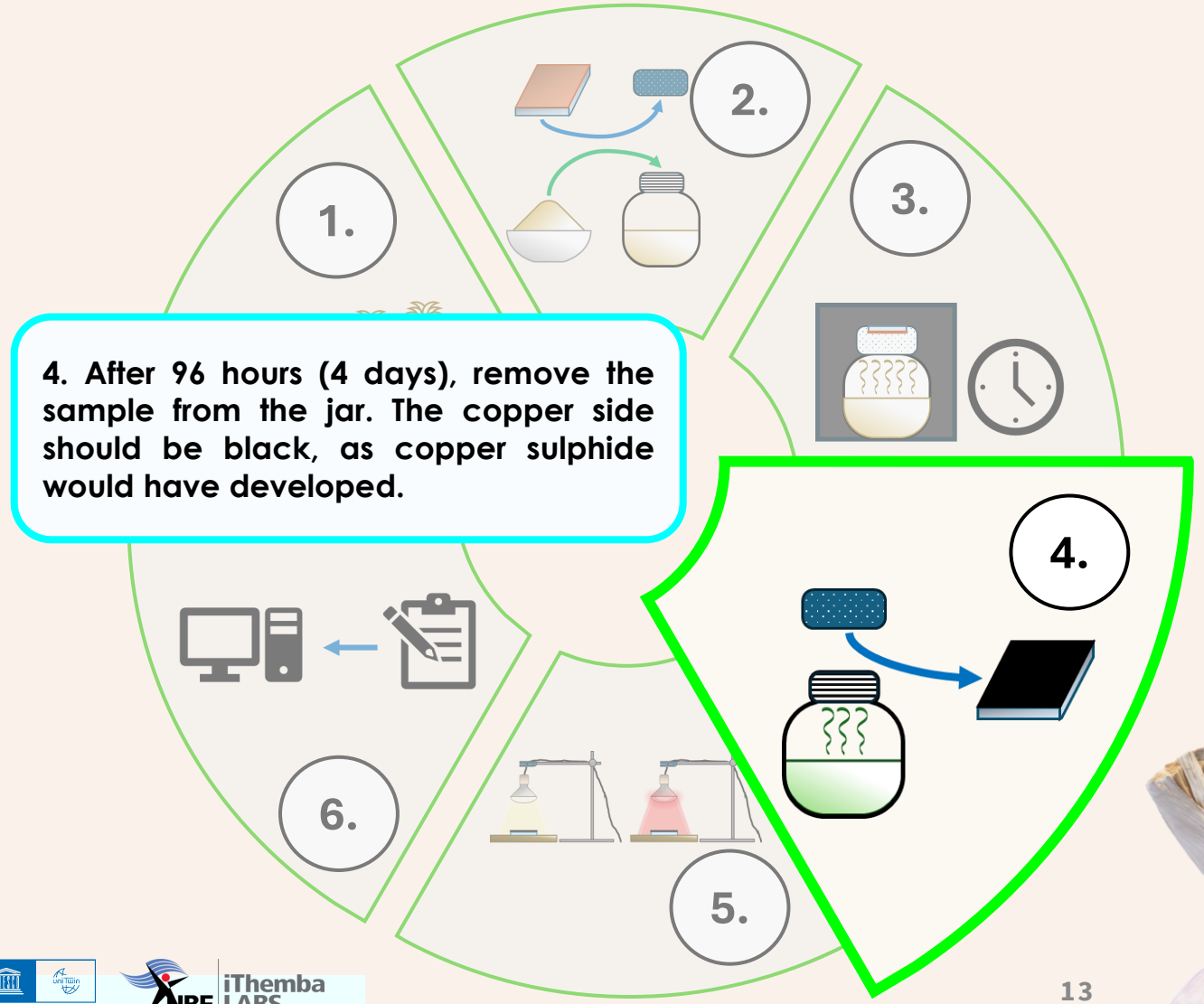
2. Prepare and clean (as appropriate) a ±1.5×1.5cm copper sample (e.g., a glass substrate with a layer of deposited copper). Find an airtight glass jar. Place the crushed garlic in the jar. Fix the copper sample (i.e., the glass side) onto the jar's lid using a temporary adhesive (e.g., Prestik) and tightly close the jar.

Experimental Procedure



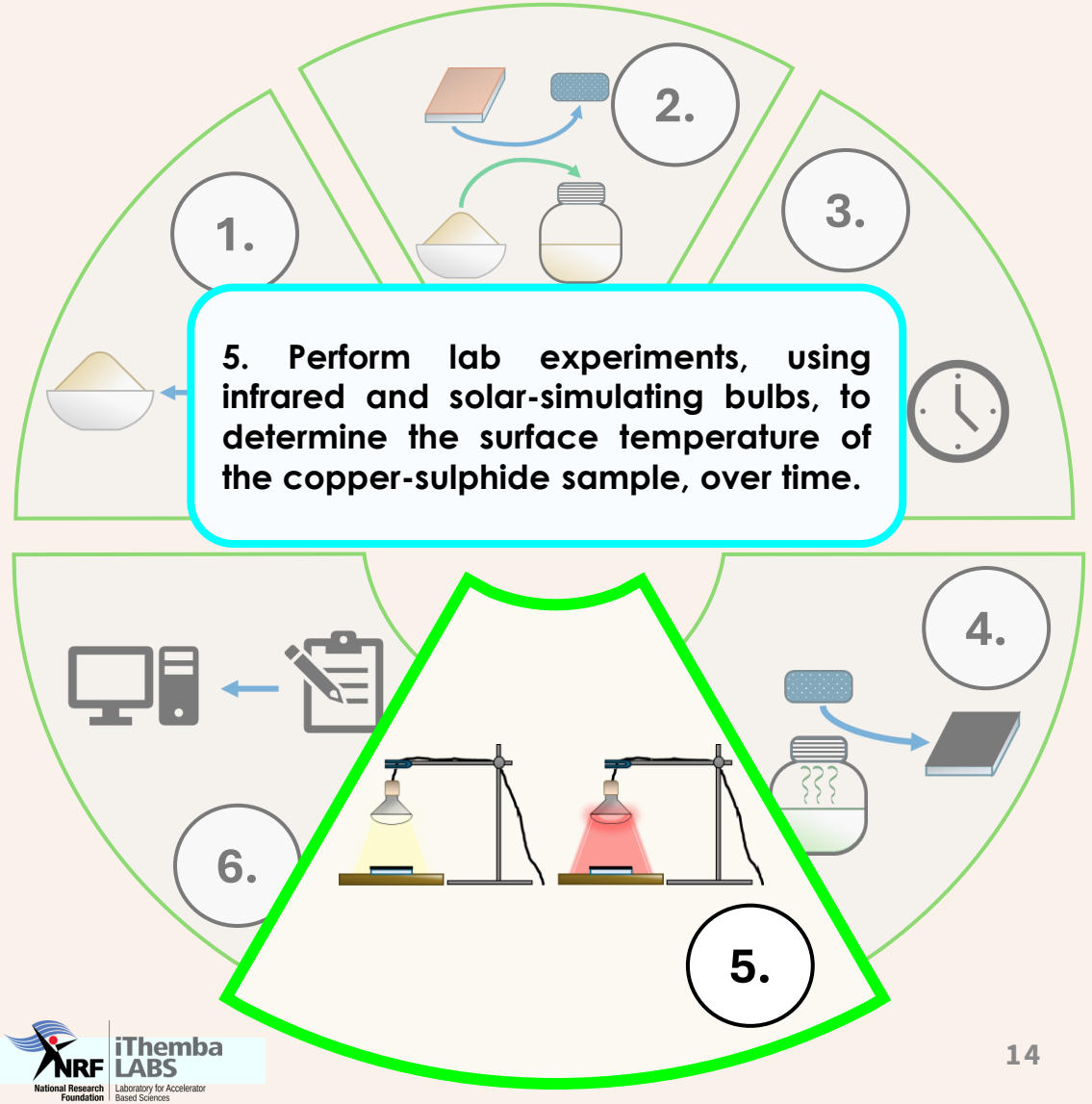
3. Wrap the jar with plastic wrap and place it in a cool, dark airtight container (e.g., a metallic tin). Set the container aside and wait for 96 hours (4 days).

Experimental Procedure

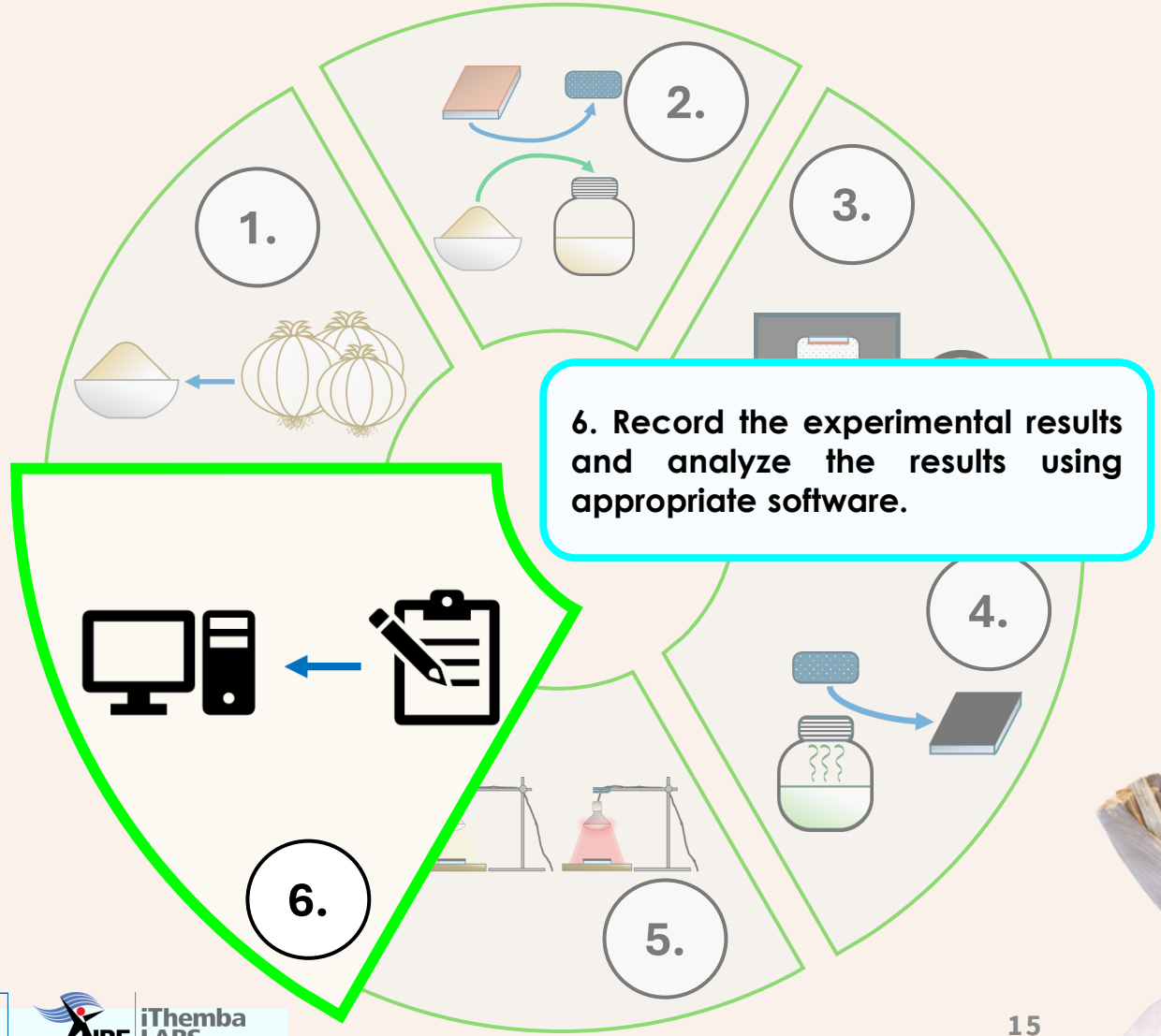


4. After 96 hours (4 days), remove the sample from the jar. The copper side should be black, as copper sulphide would have developed.

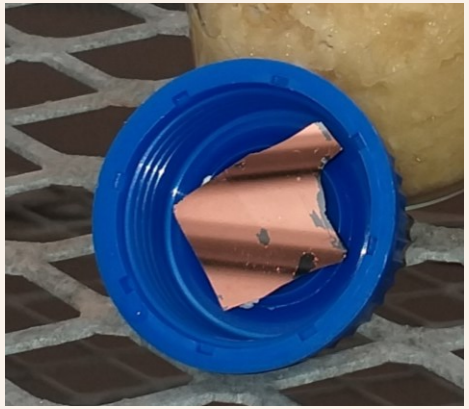
Experimental Procedure



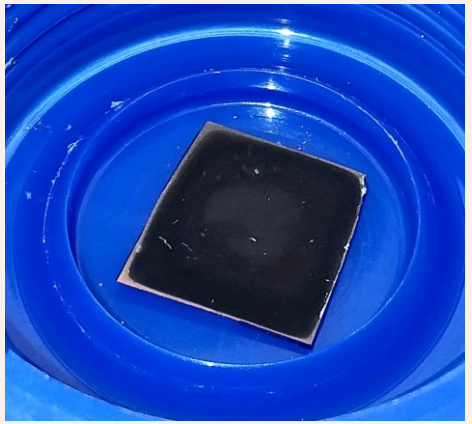
Experimental Procedure



Results



BEFORE: Cu on glass



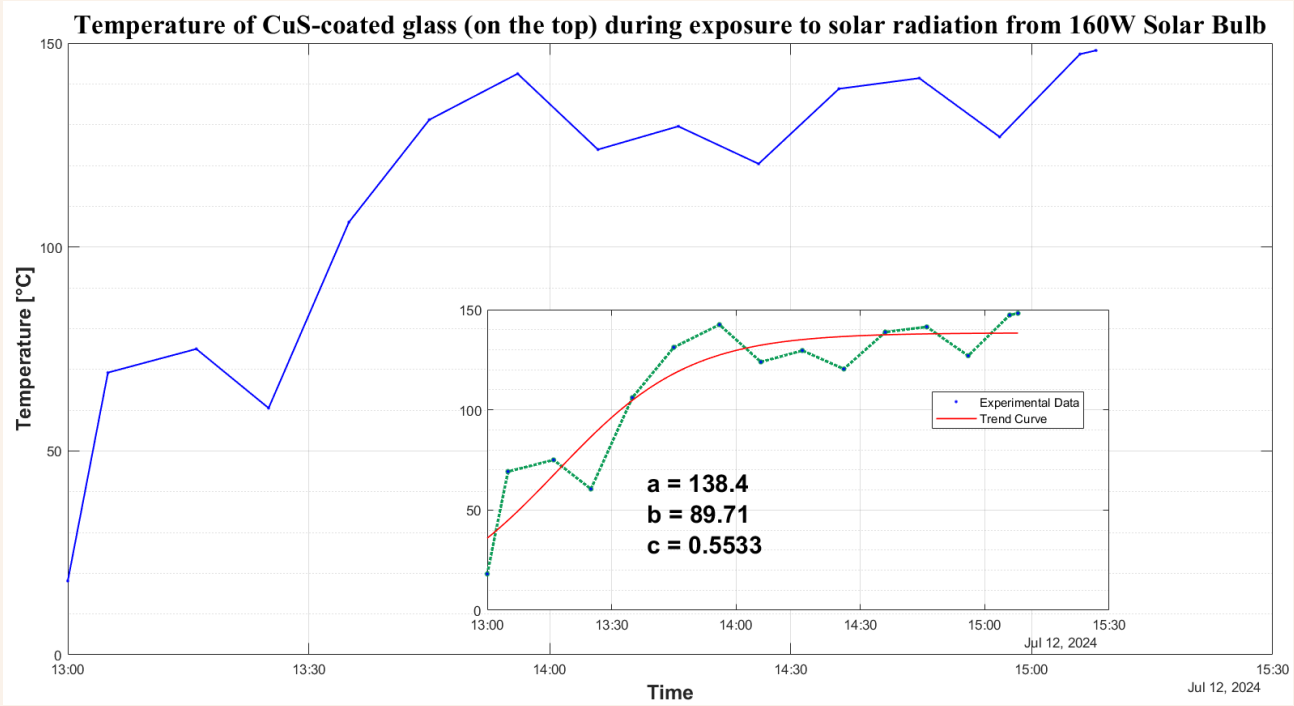
AFTER: CuS on glass

Results

Diffusion Reflectance Spectroscopy for CuS on Glass Sample (Average Reflectance ≈ 1.421%)

As seen from the plot, the diffusion reflectance spectroscopy plot shows a low average reflectance of approximately 1.4%. Additionally, in the near-infrared and infrared range, the reflectance is close to 0%, which is desirable for an application wherein one wants to maximize heat absorption.

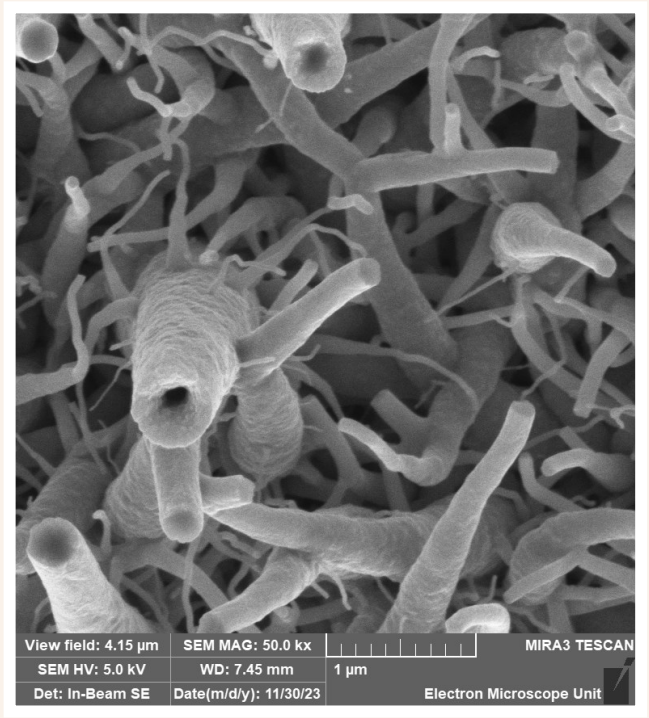
Results



Plot of temperature versus time for the surface of the CuS on Glass Sample exposed to 160W Solar Glo Bulb (Fitted Curve Steady-State Temperature ≈ 138°C)

As seen above, the plot of temperature versus time (in a laboratory setting where a 160W Solar Glo bulb was used) shows a trend whereby the temperature on the surface of the sample increases until a steady-state temperature is reached. The steady-state temperature is approximately 138°C. Such a temperature is suitable for an application that requires direct-contact or surface heating of water.

Results



SEM image of CuS developed on copper substrate
(Credit: A.S. Khameneh)

As seen above, the SEM image of CuS developed on a copper surface shows many interconnected, convoluted projections in a mesh-like arrangement. This is desirable as this implies that the surface area on a copper substate is increased, which allows for more exposure to and "trapping" of solar radiation for maximized solar absorption.

Future Work

- The bioengineered surface should be tested in an actual thermal application (e.g., water distillation).
- Other bioengineered surfaces should be investigated for their use, effectiveness and efficiency in thermal applications.

Acknowledgements

- ***Prof. M. Maaza:*** Project Supervisor
- ***Ms A.S. Khameneh (iThemba LABS):*** Assistance with sample preparation, SEM image
- ***Dr H. Mohamed (iThemba LABS):*** Assistance with diffusion reflectance spectroscopy
- ***Mr D. Kpeglo (iThemba LABS):*** Assistance with lab light-test setup

Additional 3D Figures and GIF Sources

- "Garlic" (https://skfb.ly/6Tr7S) by mjk is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).
- "Lump Grass" (https://skfb.ly/6SrXQ) by kelvladmail is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).
- GIF (Thank You Slide): https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcS4WmM4-NyGULiWsXhp84p5pXxPlaU28wFTNhYWlyJtoRhg0Yux

Thank You