KILLING BACTERIA WITH NANOHEATERS

Student(s)

Enas Sakkaamini
Basak Kuyucu

Faculty Member(s)

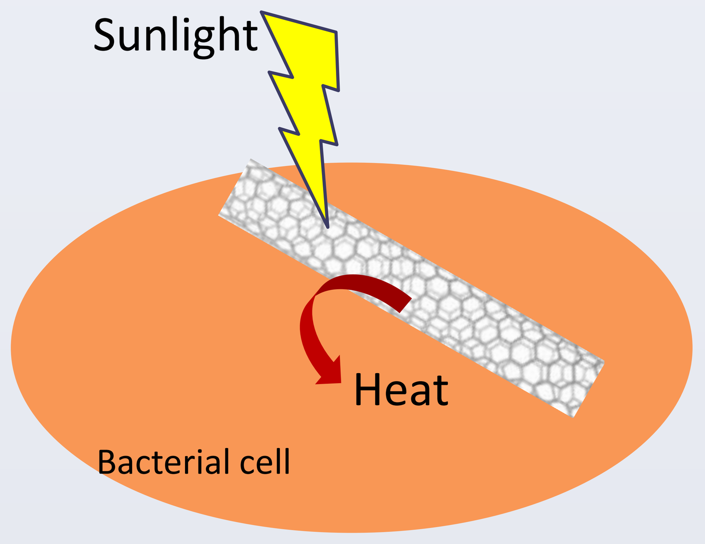
Dr. Hayriye Unal

Sabancı Üniversitesi

PURE
PROGRAM FOR UNDERGRADUATE RESEARCH

ABSTRACT

The traditional approach of treating bacteria with biochemical tools such as antibiotics is not a viable option anymore as more bacterial strains have gained resistance to antibiotics. Killing bacteria physically with the combination of photothermal agents and light provides an effective alternative method. Photothermal nanoparticles subsequently absorb the light and quickly transfer the energy into heat through nonradiative relaxation in the surrounding environment resulting in significant temperature elevations. The generated hyperthermal effect eventually causes irreparable damage to bacterial cells, leading to the death of bacteria. This process is called photothermal bacterial lysis. In this work we have studied sunlight-activated photothermal properties of multi-walled carbon nanotubes (MWNTs) and their utilization as antibacterial agents. We have also studied photothermal properties of MWNT/fluorophore hybrids where fluorophores self-assembled on the surface of MWNTs act as light harvesting antenna enhancing the light absorption capacity. We have demonstrated that MWNTs and MWNT/fluorophore hybrids can reach temperatures exceeding 80ºC when irradiated with sunlight for 9 min which results in significant antibacterial activity on *Pseudomonas aeruginosa* cells.



Photothermal bacterial lysis by carbon nanotubes

OBJECTIVES

- Studying sunlight-activated photothermal properties of MWNTs
- Designing MWNT/fluorophore hybrids with increased absorption capacity over the visible light range.
- Improving the local temperature elevations due to increased light absorption capacity.
- Studying antibacterial activity of MWNTs and MWNT/fluorophore hybrids

PREPARATION AND CHARACTERIZATION OF PHOTOTHERMAL AGENTS

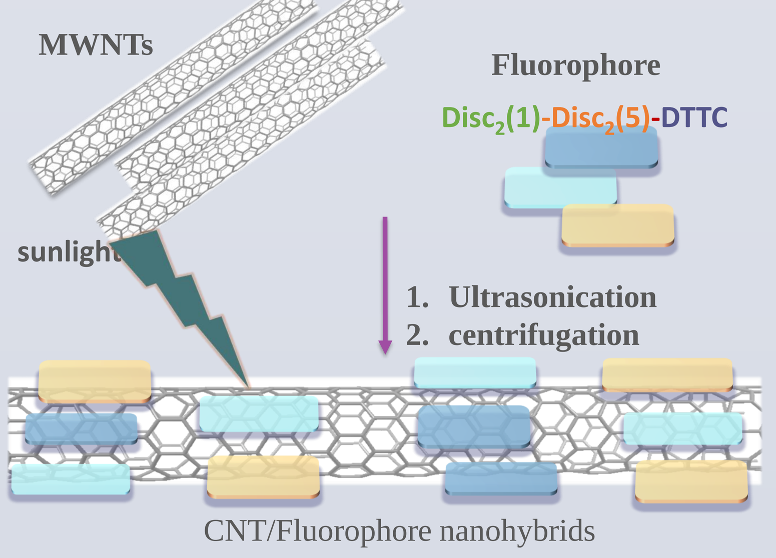
- **Preparation of MWNTs and MWNT/Fluorophore Hybrids**

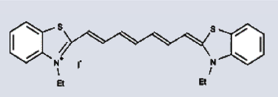
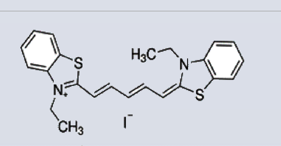
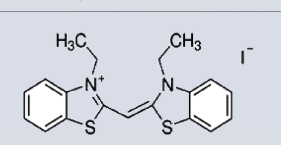
MWNT: 0.1 mg/mL MWNT in 5% Triton X-100

MWNT/Fluorophore: 50µM of each fluorophore, 0.1 mg/mL MWNT in water.

Both mixtures were ultrasonicated with a microprobe

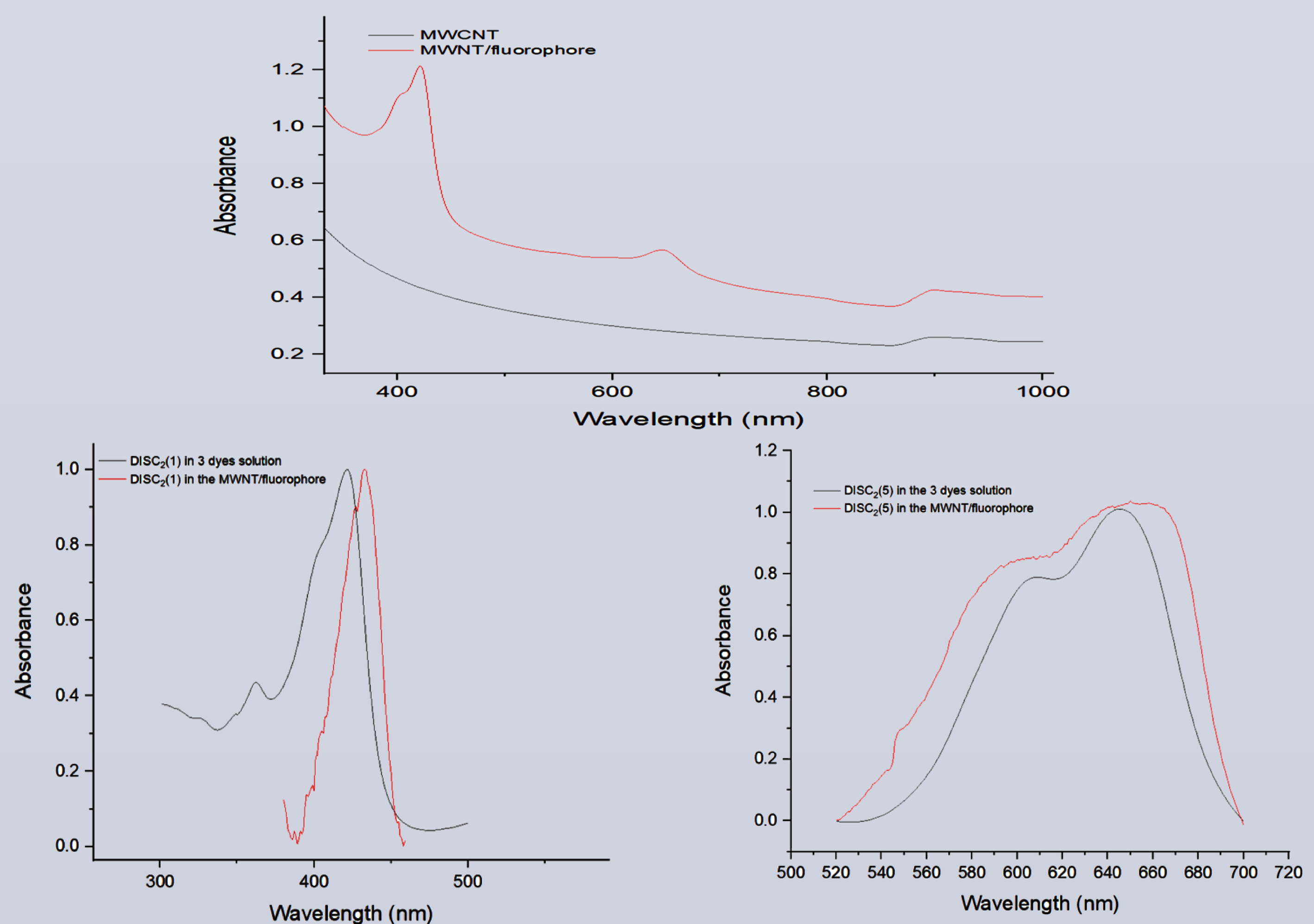
for 30 minutes in ice for the dispersion process. Later they were centrifuged for 5 minutes in order to remove undispersed MWNTs.



Fluorophores	Chemical structure	Abs_{max} (nm)
Diethylthiatricarbocyanine iodide (DTTC)		770
Diethylthiadicarbocyanine iodide ($Disc_2(5)$)		646
3,3'-Diethylthiacyanine iodide ($Disc_2(1)$)		424

- **Absorption Spectroscopy on MWNTs and MWNT/Fluorophore Hybrids**

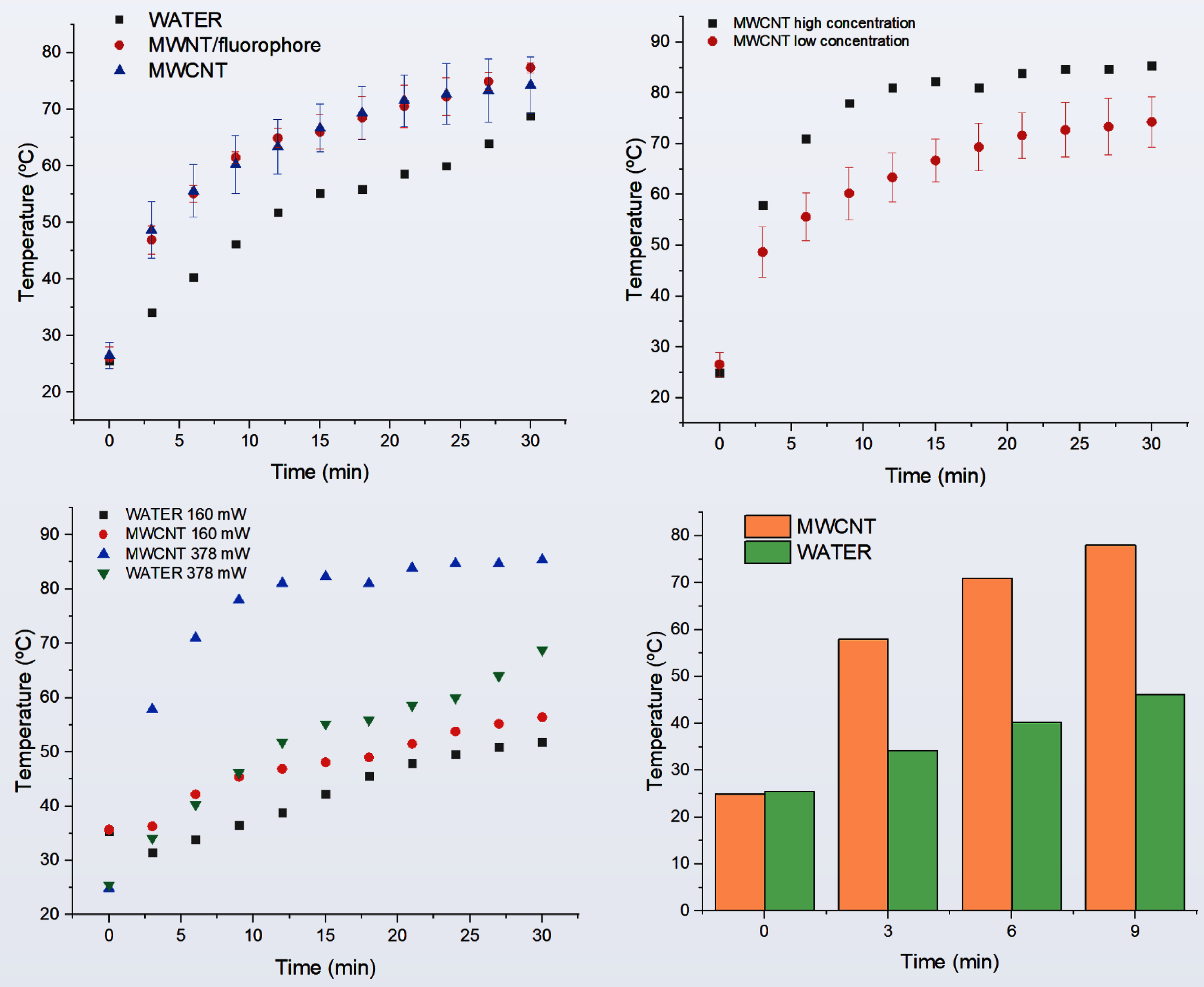
The nanohybrid formation and improvement of light absorption capacity was characterized with UV-vis spectroscopy.



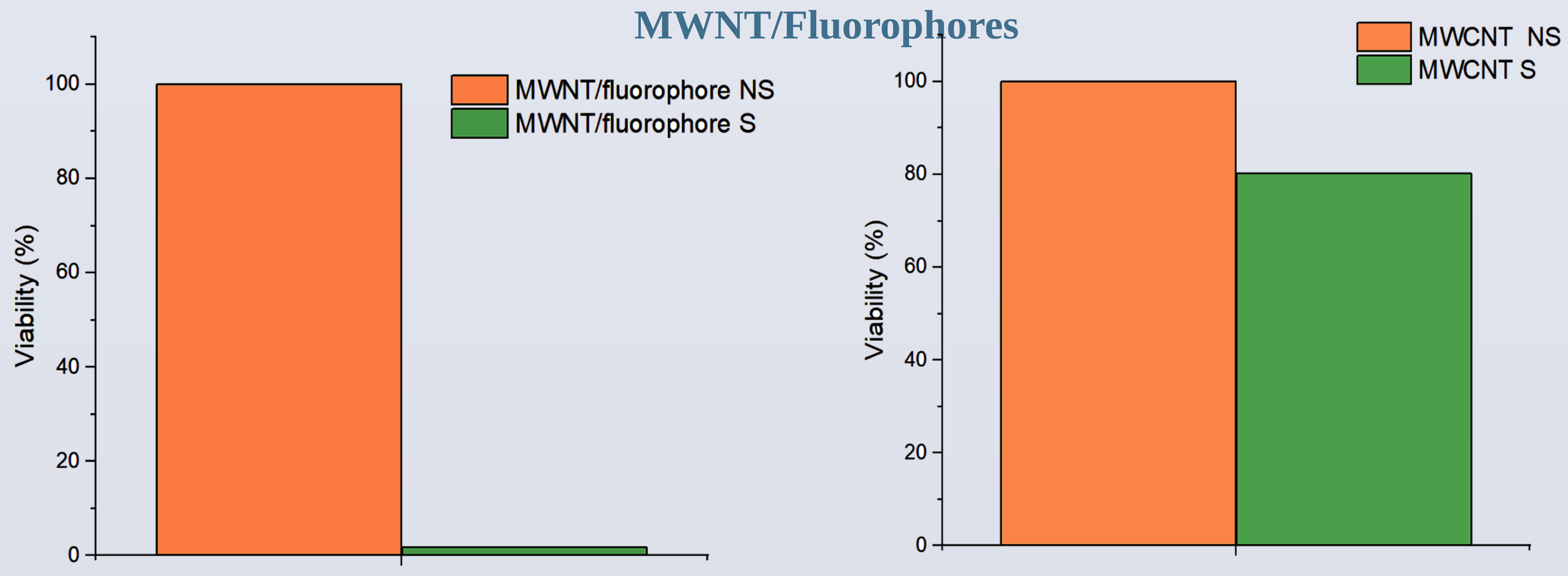
PHOTOTHERMAL PROPERTIES OF MWCNT AND MWCNT/FLUOROPHORE HYBRID

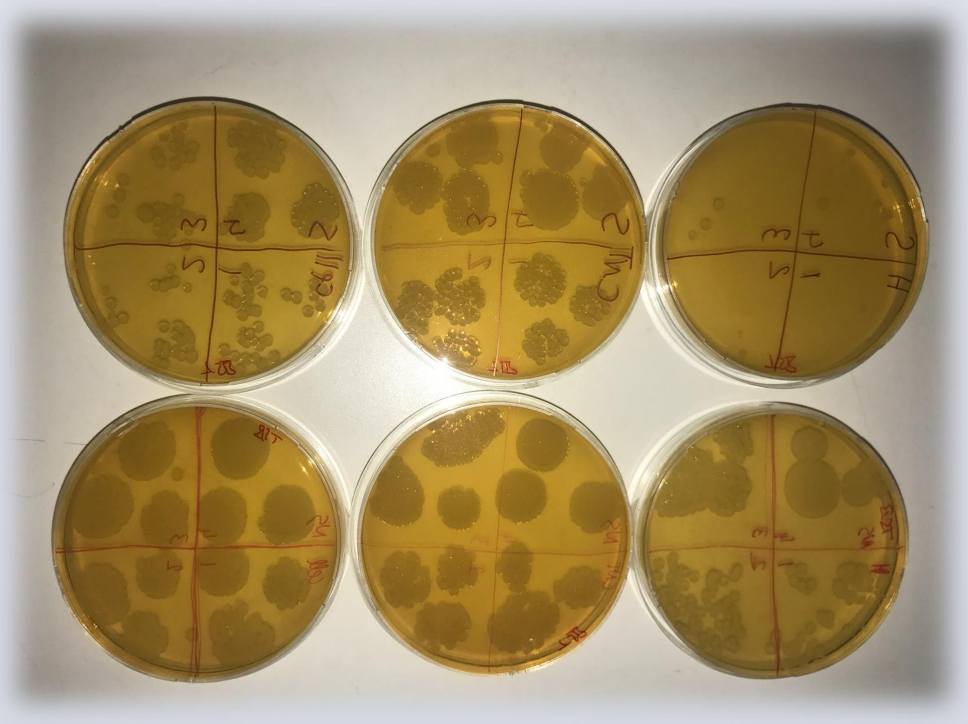
- **Time-temperature curves**

Time-dependant temperature elevations were tested using the solar simulator for 30 minutes. Multiple simulations were carried out in order to show the effect of MWNT concentrations and different sunlight power densities.



- **Viability of *Pseudomonas aeruginosa* treated with MWNTs and MWNT/Fluorophores**





CONCLUSION

Our aim was to enhance the light absorbing capacity of the MWCNT through self-assembly of fluorophores in order to increase the heat release and thus achieve higher temperature elevations. However, although flourophores bonded perfectly on the MWCNT as demonstrated by the bathochromic shift in the UV-vis spectroscopy and the hybrid did show a higher absorption capacity through out the visible range, from the solar simulator data both the hybrid and the MWCNT solutions got to the same temperature at almost the same rate so we focused later on with our experiments on MWCNTs. We repeated the simulation with low and high CNT concentration and with the higher CNT concentration we achieved 70℃ in 6 min. But with the lower concentration 70℃ was achieved in 25 min. This shows us that the CNT is the one causing the temperature elevation. The data from the solar simulator showed us that the MWCNT was reaching around 75ºC in 6 minutes so when tested on the bacteria 6 minutes was enough to kill the bacteria. For the viability test on the bacteria MWCNT and hybrid kill cells even before sunlight as they are inherently antibacterial, but this antibacterial activity is enhanced several times after sun light irradiation due to the photothermal effect. However these results are preliminary and can be optimized by repeating the experiments at least 2 more times to get the final result, and also at different conditions like power and time.