Enhanced photon energy conversion of iron oxide nanoparticle via ligand-to-metal charge transfer process for photothermal antibacterial activity

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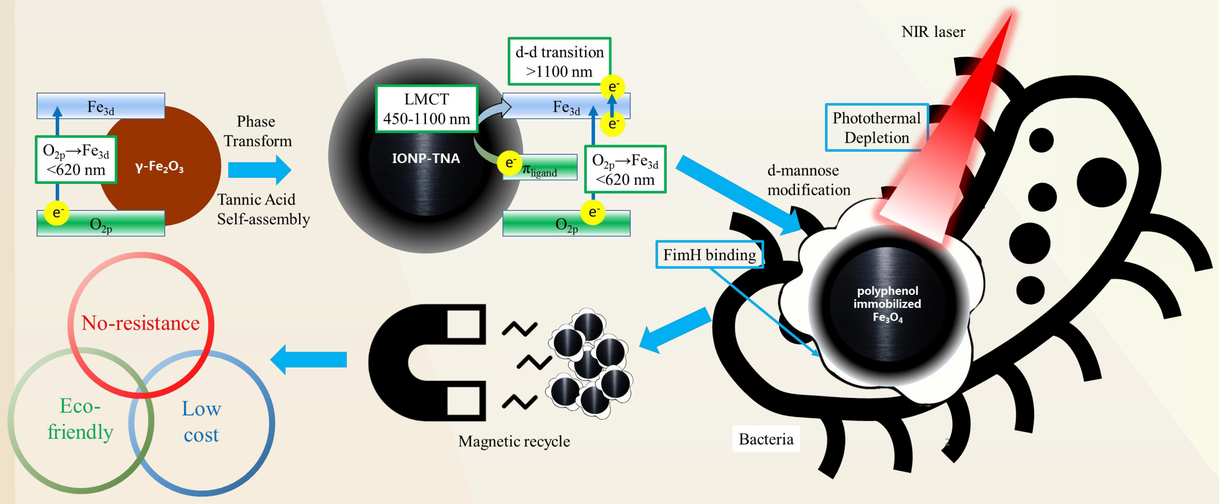
Abstract

We demonstrate a high photothermal conversion efficiency iron oxide nanoparticles with extending absorption spectrum from UV to NIR. In environment area, we present the solar driven photothermal antibacterial activity. For therapeutic application, we choose the high tissue transmittance 808nm NIR laser to prove the inhibition of microbial infection.

Introduction

In 2012, World Health Organization (WHO) published a report about antibiotic abusing, "*The evolving threat of antimicrobial resistance*" . As the antibiotic abusing occurs in hospital or farm, the breeding multidrug resistant bacteria will transfer to the worldwide. Since bacteria shows weak resistant to nanoparticles, there were more and more studies report the antimicrobial activity in nanotechnology.



Scheme.1 The overall objective of the iron oxide nanoparticles on selective wavelength PTT for antibacterial activity

We introduce polyphenol immobilized Fe_3O_4 nanoparticle (PFNs) with broad absorption spectrum from ultraviolet to near infrared region. The wide covering of absorption spectrum suggests the numerous choices of wavelength for PTT application.

In this study, we demonstrate NIR light source to induce the photothermal conversion effect and cause the bacteria depletion. For more sufficient bactericidal effect, we modified D-mannose on the PFNs surface, which lead to the adhesion of nanoparticles on the FimH protein of Escherichia coli fimbriae. Under NIR (808nm, 135mW) laser irradiation, the D-mannose modified PFNs (DMPFNs) could sterilize the Escherichia coli up to 100%. For solving the antibiotic abusing problem, it's a new step to confront the drug resistant bacteria.

Because of the overlapping of the absorbance spectrum and the solar light source, we further expect the potential for solar light induced photothermal bacteria ablation. The mother nature light source for environmental application should be a novel idea in biophotonics field.

Results

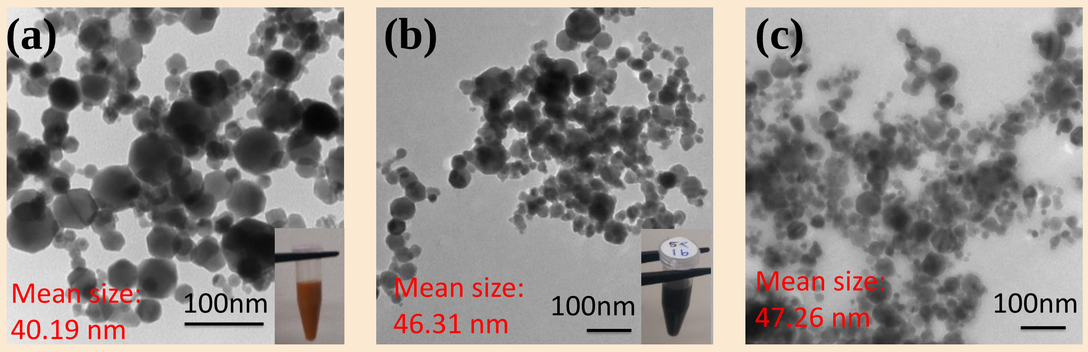


Fig.1 TEM image of (a) γ-Fe_2O_3 (b) PFNs (c) DMPFNs NPs The inserts image show the photo of materials.

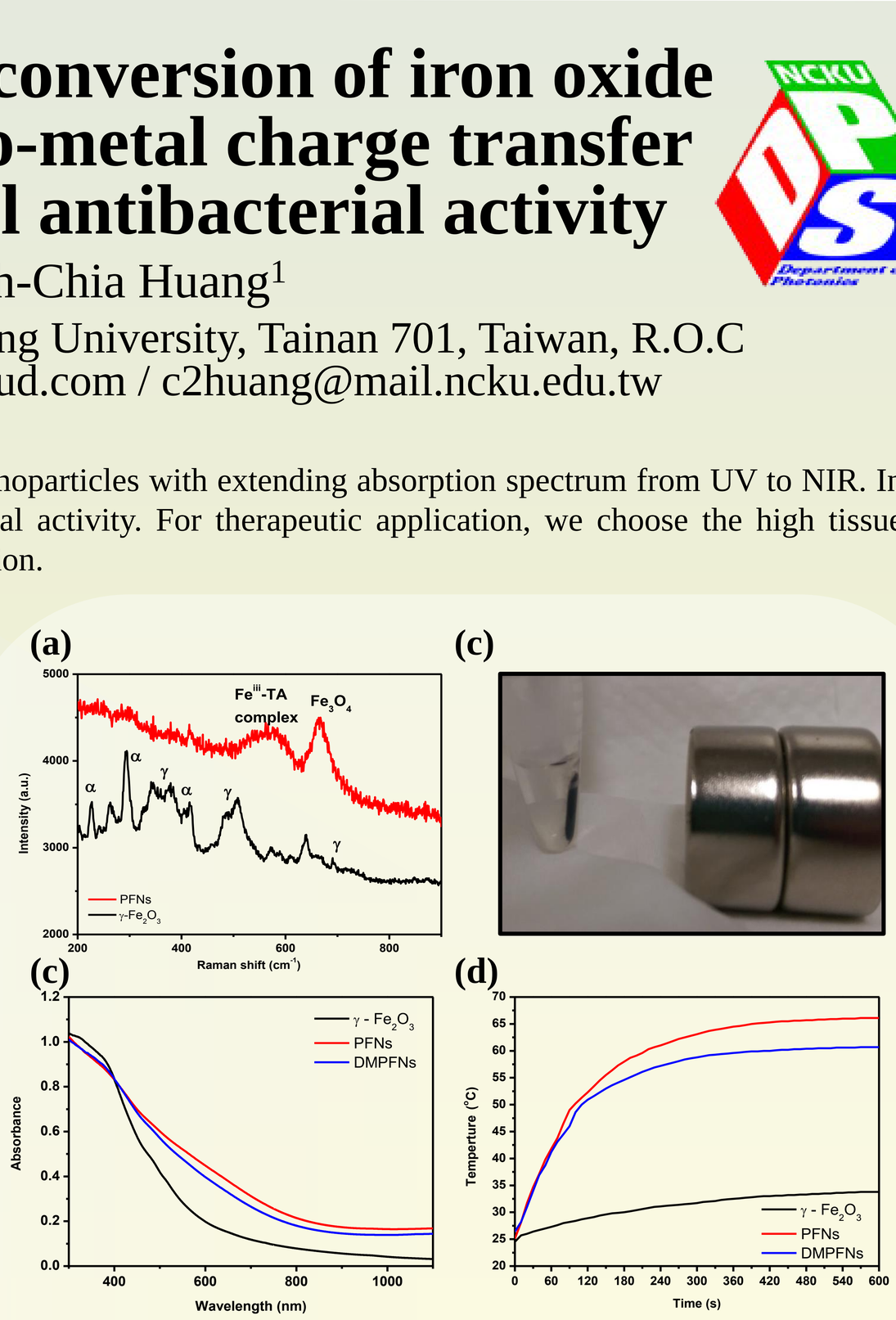


Fig.2 (a) Raman Spectrum of γ-Fe_2O_3 and PFNs for phase checking (b) magnetism exhibition by external magnetic field (c) UV-vis spectrum of γ-Fe_2O_3 ,PFNs and DMPFNs (d) temperature change under 808 nm laser (135mW) irradiation

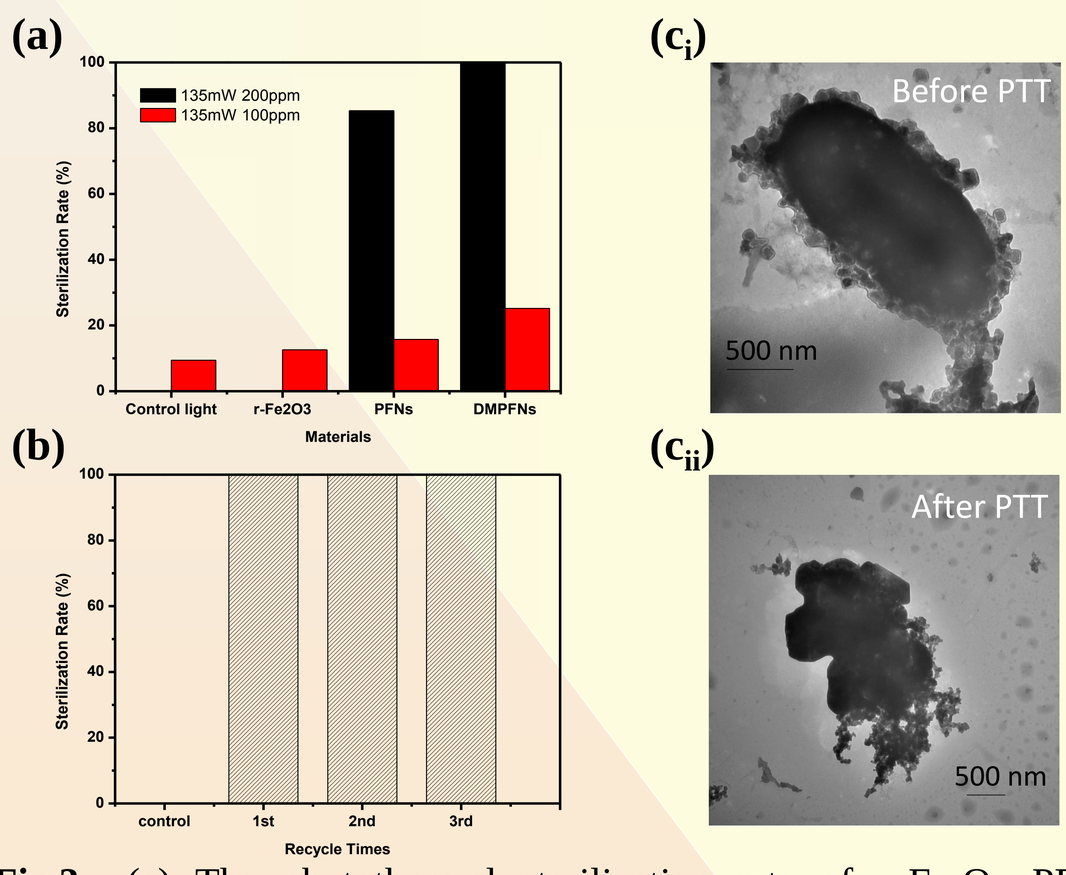


Fig.3 (a) The photothermal sterilization rate of γ-Fe_2O_3 ,PFNs and DMPFNs in different material concentration(100, 200ppm) under 808 nm laser (135 mW) (b) Magnetic recycle photothermal bacterial ablation sterilization rate for 3 times treating (c) TEM image of E.coli and DMPFNs interaction before (c_i) and after (c_{ii}) irradiation

Conclusion

We demonstrate the efficient NIR photothermal antibacterial activity by d-mannose modified polyphenol immobilized Fe_3O_4 NPs. Since the sufficient photothermal conversion improvement from 6.59% to 30.24%, the NPs binding on the bacteria cell wall could directly destroy the bacteria causing necrosis. On the other hand, the broad absorption band show the potential for the solar light induced antibacterial activity.