NANOPARTICLE-AIDED MICROWAVE HYPERTHERMIA: OBSERVING INNOVATIVE FREE RADICAL GENERATION

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Outline

- Background Material
  - Hyperthermia
  - Nanoparticles (NPs)
- Experimental technique
  - Free radical measurement
  - Electron Paramagnetic Resonance (EPR)
- Results and Discussion
- Conclusions

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Hyperthermia

- Hyperthermia
  - One of the oldest methods of cancer treatment
  - Tumor heated above body temperature (42 - 45 °C)
  - Used alone or more commonly in adjuvant to radiation/chemotherapy
- Microwave hyperthermia
  - One of the new approaches used to heat tumors
  - Good option for recurrent prostate cancer
  - And other superficial tumor treatments
- Major objective: maximize tumor cell kill due to elevated temperature while minimizing normal structures heating
- One of the approaches: NP aided MW hyperthermia

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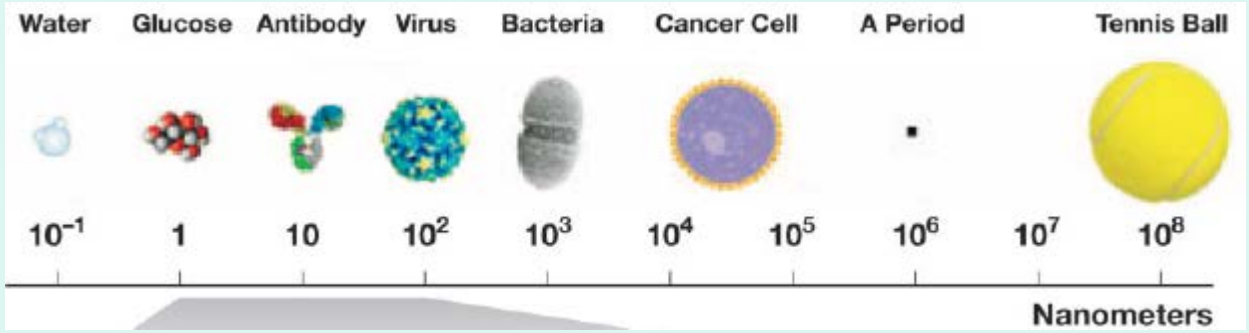
Nanoparticles (NPs)



- Nanoparticle dimension: 1-100 nm
  - 1,000 to 10,000 times smaller than living cells
  - Biocompatible & selective absorption in tumors
  - Enhance radiation effects
- AuNPs: non toxic at clinically achievable concentrations
- Pt: used in chemotherapeutic agents for long time

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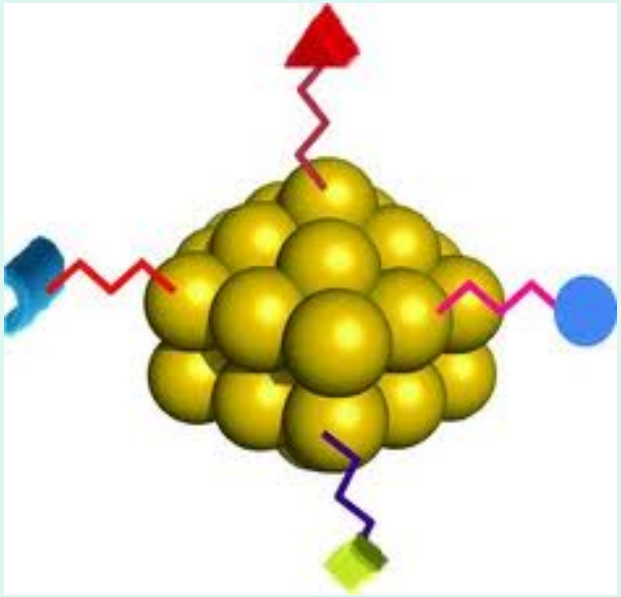
NPs in Tumor Heating

- Offer selective tumor heating under radiofrequency or microwave radiation
- Enhance tumor cell kill
- Heating effect depends on NP concentration
- Effects beyond the effect of heating observed: speculated that interaction of MW with NP surface Plasmon, electrical discharge of NPs and other unknown effects play role



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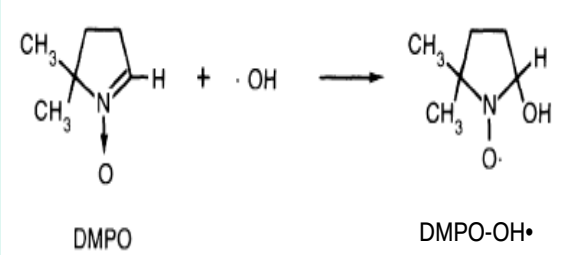
Experimental Technique

- Colloidal nanoparticles with 3.2 nm dimension
- Concentration: 10 and 20 ppm AuNP, and 10 ppm PtNP
- 9.68 GHz MW frequency for irradiation and detection
- DMPO to trap OH• radicals



- Electron paramagnetic resonance (EPR) Spectroscopy for DMPO-OH• measurement

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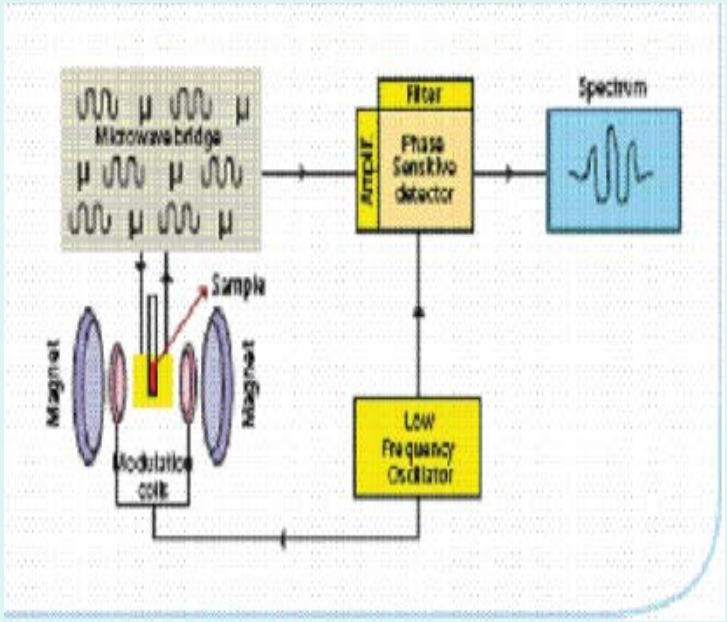
Electron Paramagnetic Resonance (EPR)

- Standard technique of free measurement
- Exploits paramagnetic property of free radicals that arises due to unpaired electron(s)
- Quantitative measurement possible



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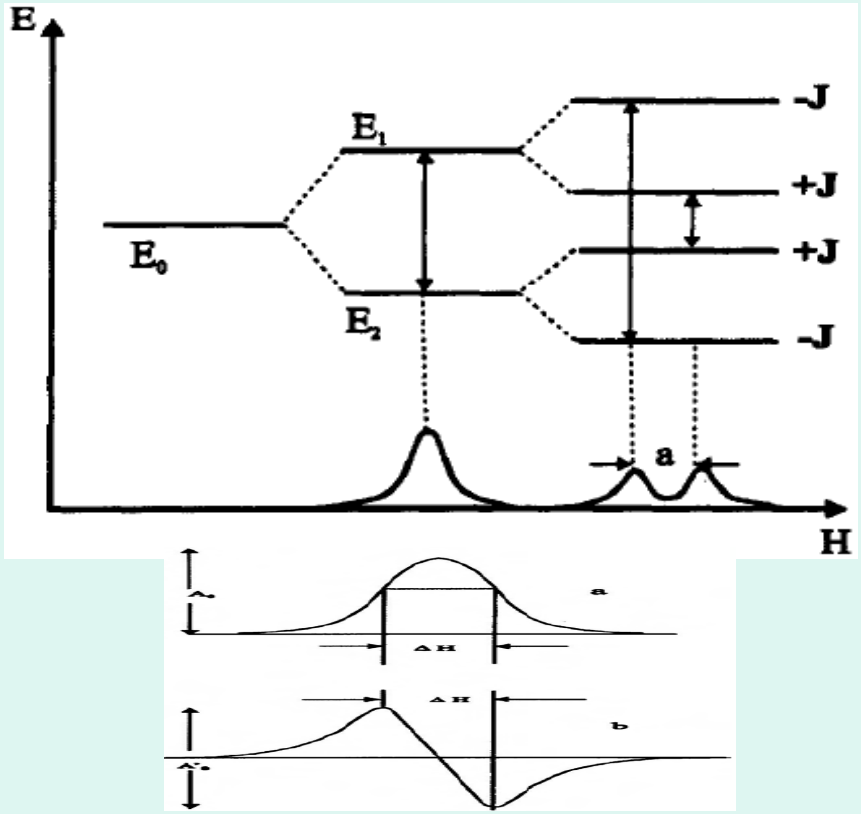
Basics of EPR

- Variable B field and constant frequency microwave applied simultaneously
- Spin energy levels undergo
  - Zeeman splitting
  - Hyperfine splitting
- Electrons transit between two split levels
  - Source of signal in EPR
- Signal Recorded as first derivative



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Results and Discussion

- DMPO-water solution exposed to MW: no radical signal detected
- DMPO-water solution exposed to clinical Ir-192 HDR source
  - OH• radical signal detected
  - Intensity increased with the increase in dose delivered
- DMPO-colloidal AuNP/PtNP (not having intentionally added radicals) exposed to MW: OH• radical signal developed

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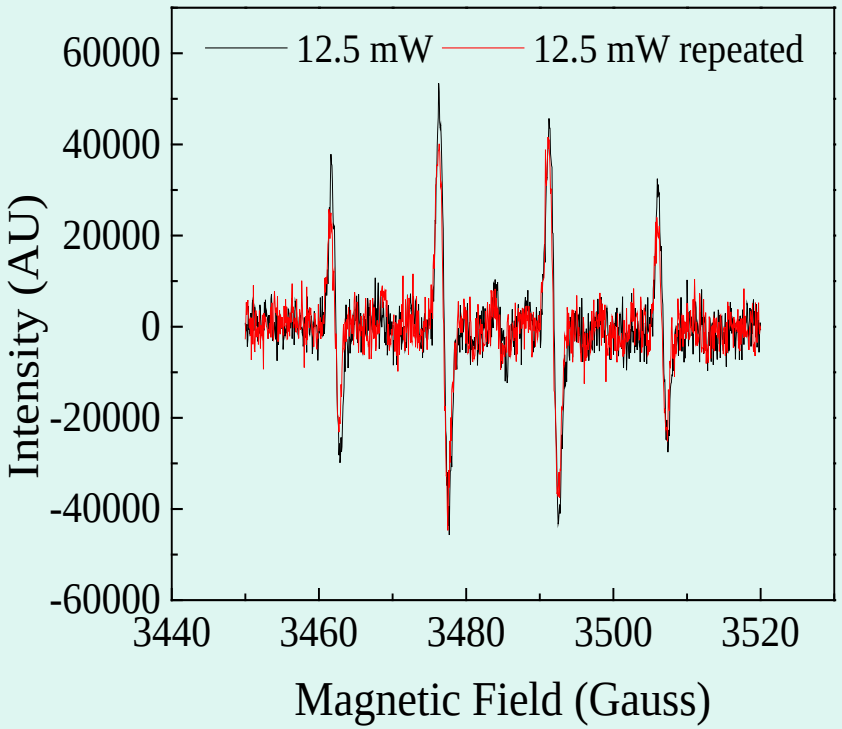
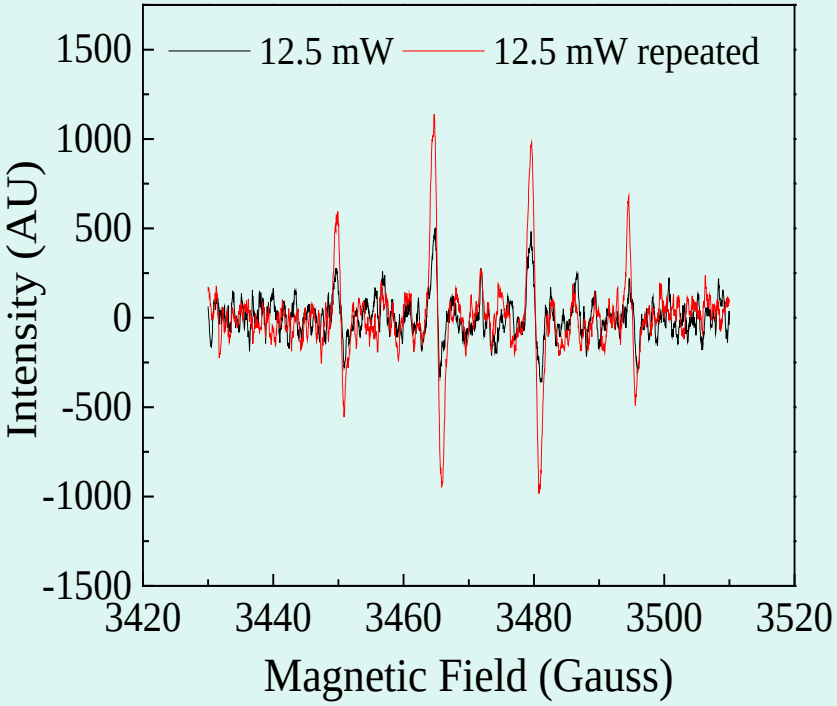
Results and Discussion



EPR spectra of OH• radical from water samples exposed to Ir-192 source



EPR spectra of OH• radical from 10 ppm AuNP colloid

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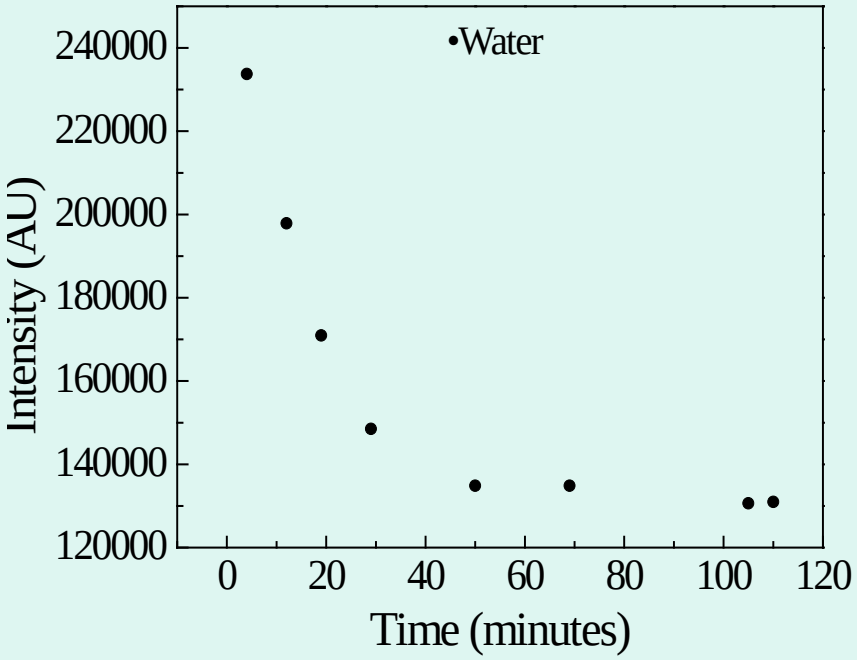
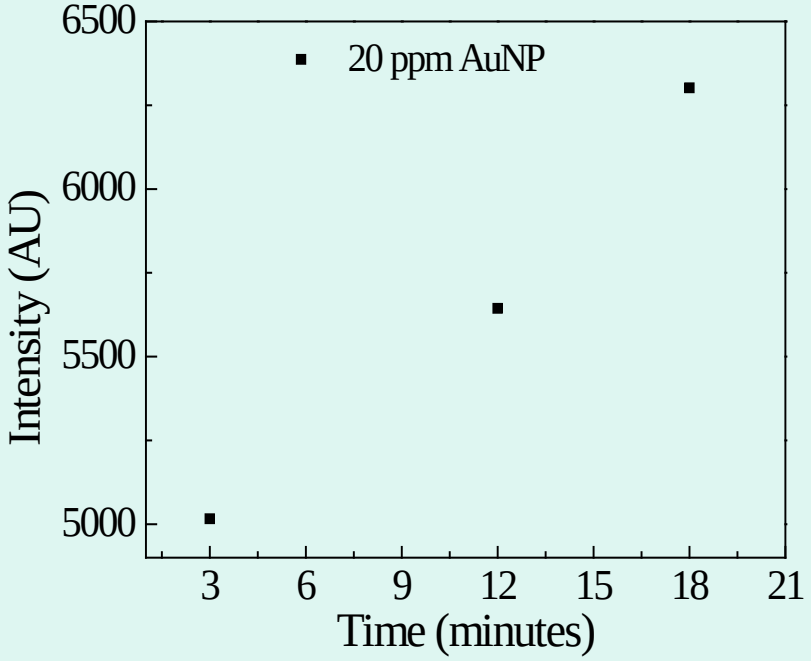
Results and Discussion



Decay of OH• intensity from water irradiated with Ir-192 HDR source under the exposure to MW radiation



Increase of OH• intensity from AuNP colloid under the exposure to MW radiation

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Results and Discussion

- NP colloids exposed to MW developed radical signal
- In contrast to the radical intensity decay with time
  - OH• intensity comparison at 12.5 mW microwave power show increased intensity ~10-60 % in 4-6 scans (14 samples used)
  - Increase depended on the number of scans, time span between initial and final scans, and on the intermediate MW power applied
- OH• intensity developed by 10 ppm PtNPs close to the one developed by 20 ppm AuNPs within experimental error

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Conclusions

- Gold and platinum nanoparticles generate free radicals under microwave irradiation
  - Microwave energy ~ 4×10^{-5} eV << 7.4 eV (excitation energy of water molecule) confirms catalytic property of NPs under MW radiation
  - Interaction of MW with NP surface Plasmon, electronic discharge of NPs: possible reasons
- Free radicals generated by NPs augment cell killing effect of MW heating
- PtNPs more effective than AuNPs in radical generation under MW irradiation
- To the best of our knowledge, these results are not reported in literature

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