2022 KY INBRE Electron Microscopy Summer Workshop

Development of wüstite nanoparticles as efficient ROS-inducing agents for cancer therapy

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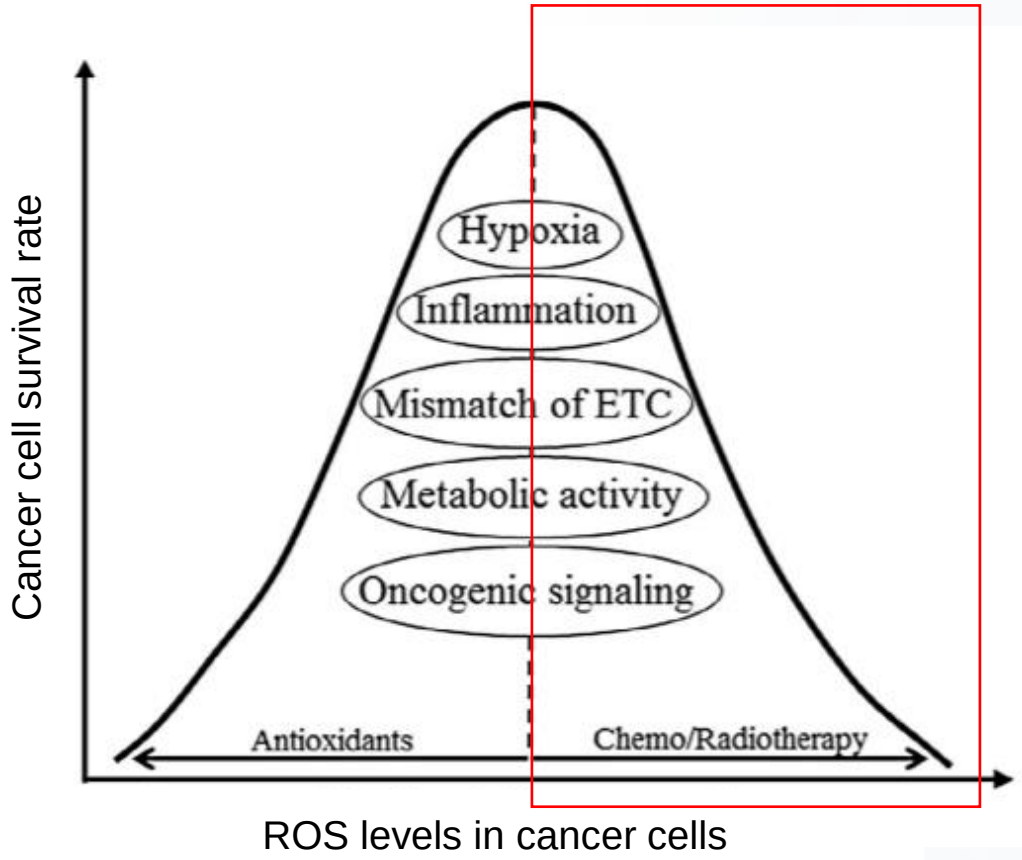
Cancer therapy



The roles of intracellular reactive oxygen species (ROS) levels in cancer therapies. Either higher or lower ROS levels can reduce the survival of cancer cells via multiple pathways.

Fenton reaction

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \mathbf{OH\bullet} + OH^- \quad (1)$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + \mathbf{OOH\bullet} + H^+ \quad (2)$$

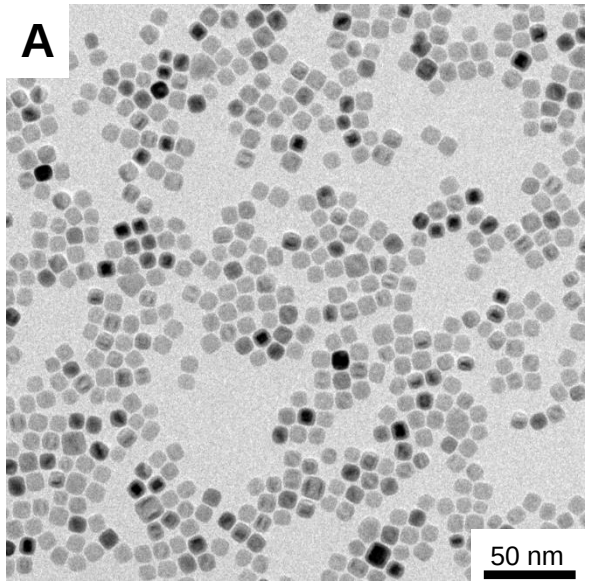
Type of iron oxide:

1. Oxide of Fe^{2+}
   - FeO: iron(Ⅱ) oxide, **wüstite**
   - FeO_2: iron dioxide
2. Mixed oxides of Fe^{2+} and Fe^{3+}
   - Fe_3O_4: iron(Ⅱ, Ⅲ) oxide **magnetite**
   - Fe_4O_5, Fe_5O_6
1. Oxide of Fe^{2+}
   - Fe_2O_3: iron(Ⅲ) oxide
     - α-Fe_2O_3 -hematite
     - β-Fe_2O_3
     - γ-Fe_2O_3 -**maghemite**

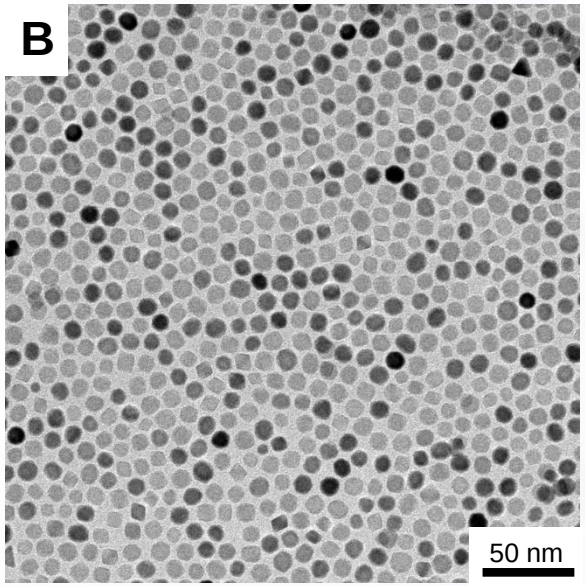
Huang. *Oxidative Medicine and Cellular Longevity.* 2020

Iron oxide nanoparticles (different compositions)

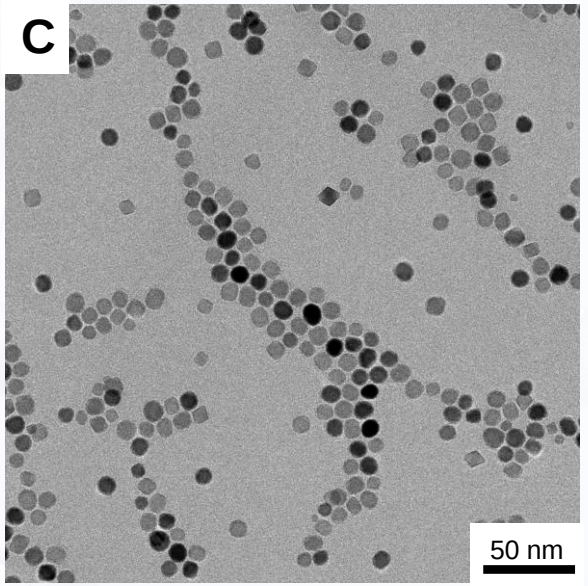
15.5nm (±0.8) wüstite nanoparticles



15.1nm (±1.1) maghemite nanoparticles

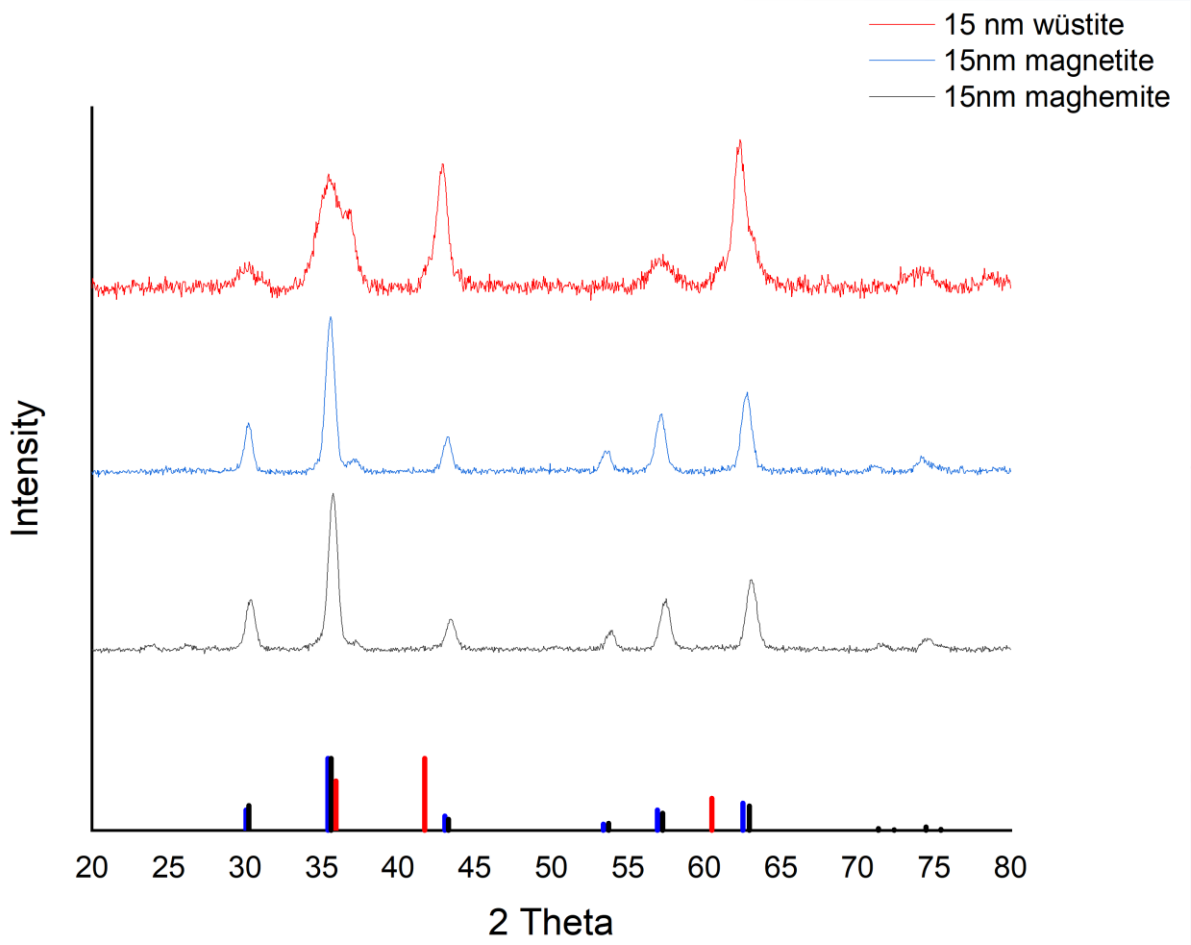


15nm (±1.3) magnetite nanoparticles



The TEM image of iron oxide nanoparticles. The size of nanoparticles was measured with TEM images in image J (n > 1000).

XRD (Crystal Structure)

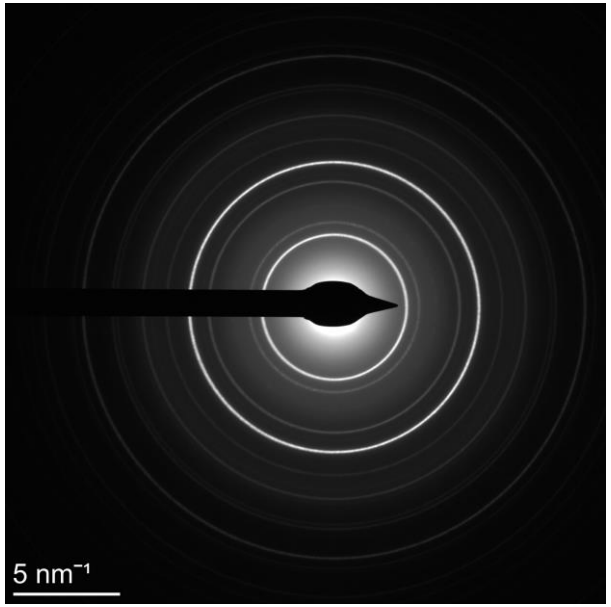


	Lattice parameter(a)	**Standard lattice parameter**(a)
15 nm wüstite nanoparticles	4.278 nm	4.296 nm
15nm magnetite nanoparticles	8.368 nm	8.378 nm
15nm maghemite nanoparticles	8.331 nm	8.340 nm

XRD patterns of iron oxide nanoparticles. The figure shows the XRD pattern of 15nm magnetite, maghemite, and wüstite nanoparticles.

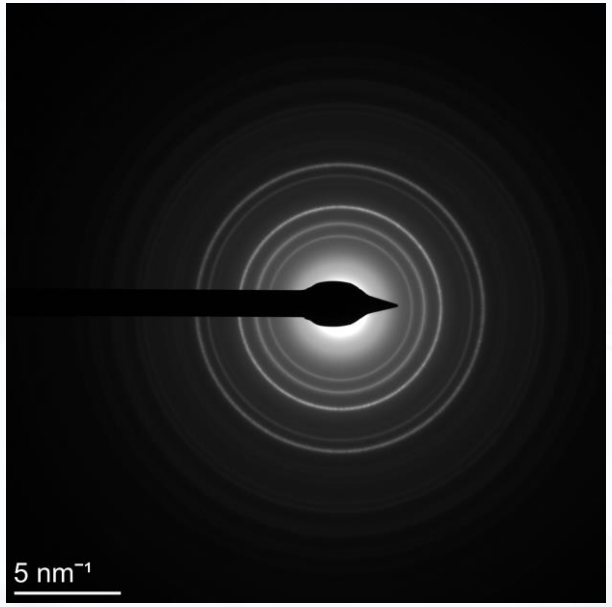
SAED (Crystal Structure)

15nm magnetite nanoparticles



Ring			
	1	2	4
d(Å)	2.94	2.53	1.47
Fe_3O_4	2.96	2.52	1.48
hkl	2 2 0	3 1 1	4 4 0

15nm wüstite nanoparticles

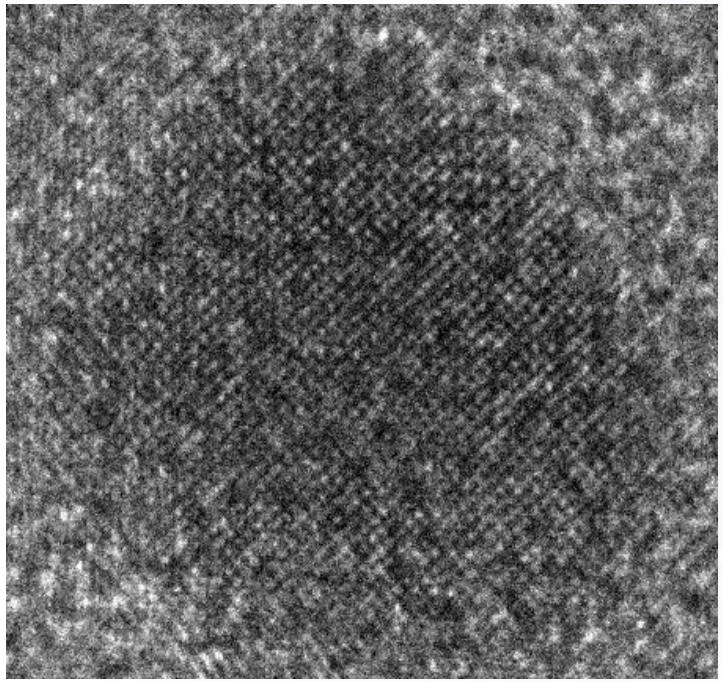


Ring				
	1	2	3	4
d(Å)	2.96	2.54	2.11	1.48
FeO		2.49	2.16	1.53
hkl		1 1 1	2 0 0	2 2 0

SAED patterns of iron oxide nanoparticles. The figure shows the SAED pattern of 15nm synthesized magnetite and wüstite nanoparticles.

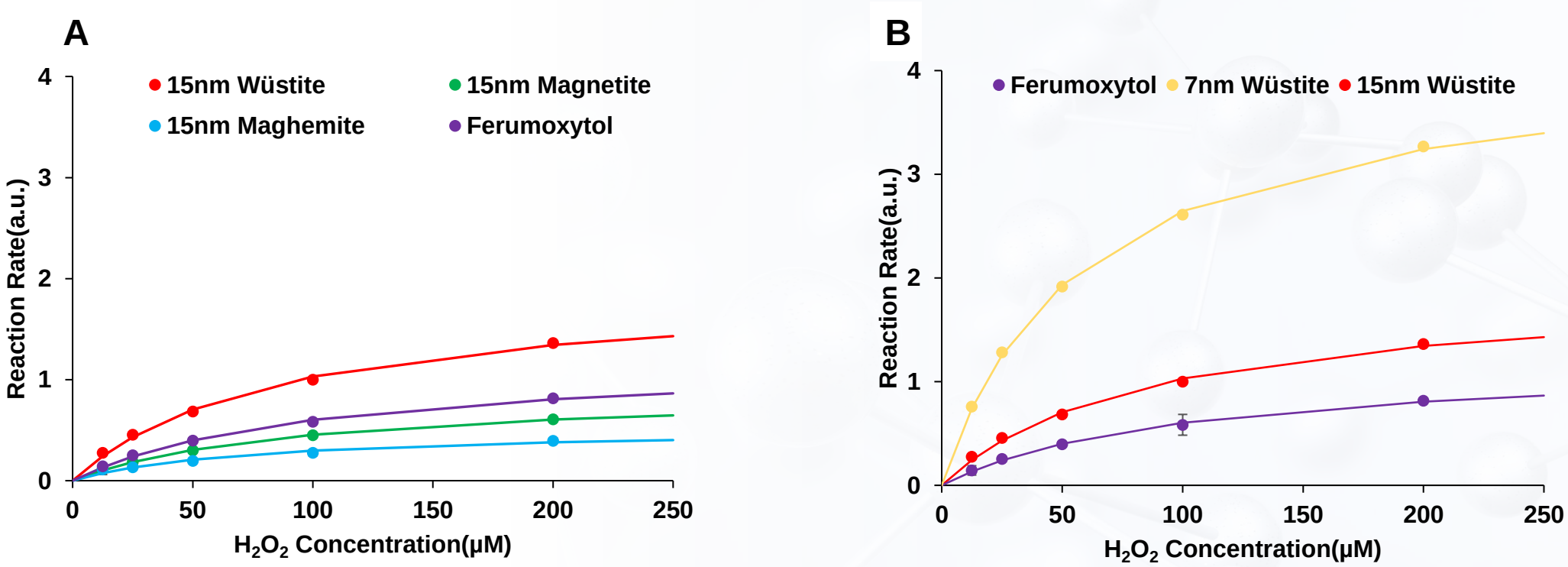
HRTEM

15nm wüstite nanoparticles



HRTEM image of 15 nm wüstite nanoparticles. It is difficult to calculate lattice parameters due to low resolution.

Dependence of catalytic activity on the size and composition of nanoparticles



Michaelis–Menten curves for IONPs.(A) Wüstite nanoparticles have higher catalytic activity. (B) The ROS generation increased as the size of nanoparticles decreases.

EM methods used

1. TEM → size

2. XRD and SAED → composition

Conclusions

1. We have developed methods for synthesizing wüstite, magnetite, and maghemite nanoparticles of different sizes.

2. Compared with magnetite and maghemite nanoparticles, **wüstite nanoparticles** have higher catalytic activity. As the wüstite particles' size decreases, the catalytic activity will be increased.

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