Combating Cancer with Magnetic Nanoparticles

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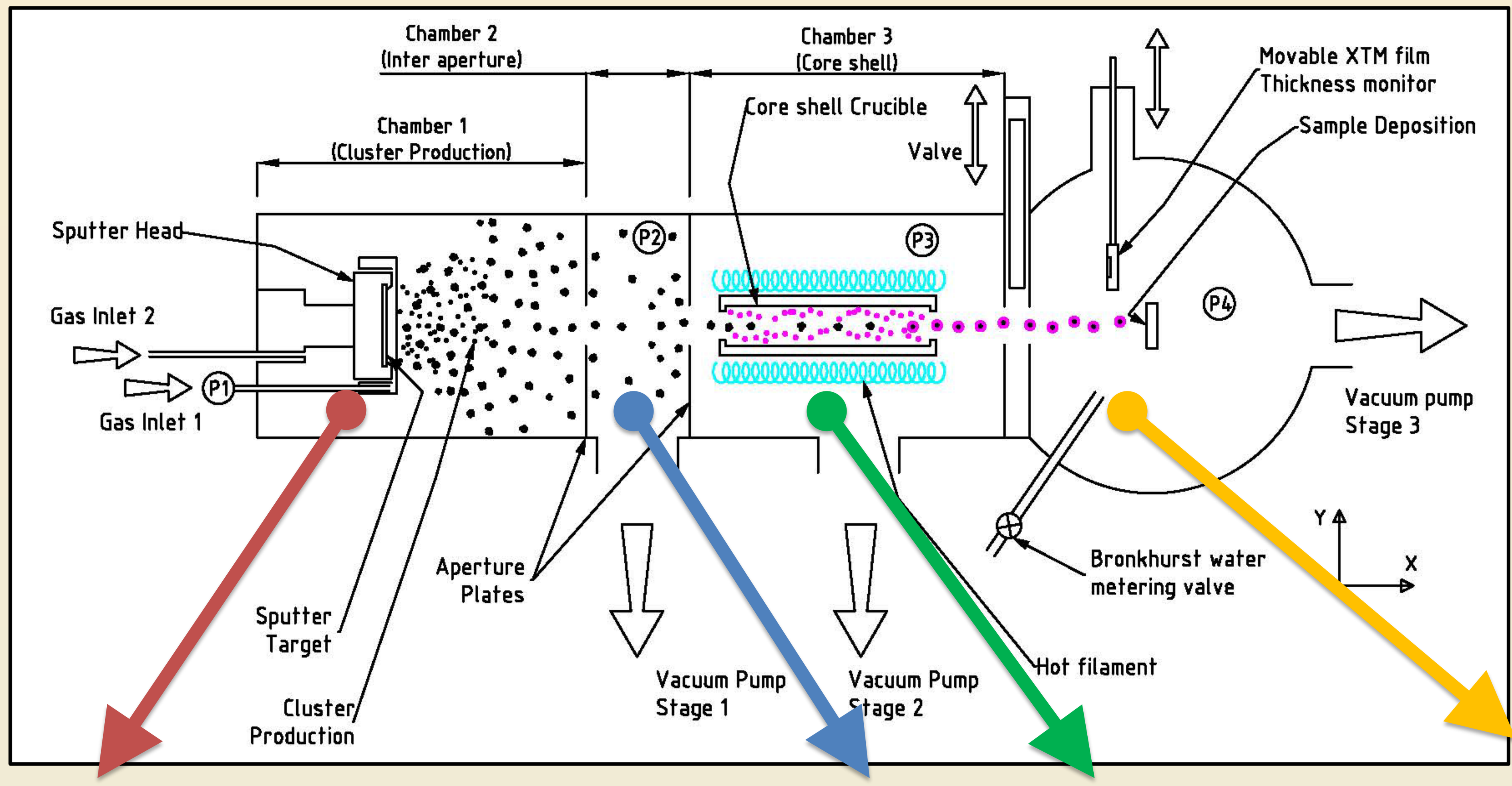
Nanoparticle Synthesis



Key Attributes of Source:

- Ultra-High Vacuum conditions
- Independent variation of the core size and shell thickness
- Independent selection of core and shell material
- Deposition into water
- The flexibility of the method allows optimization of the nanoparticle performance in Magnetic Nanoparticle Hyperthermia (MNH) – see right – and MRI Contrast agents

Chamber 1: Iron (Fe) nanoparticles are produced with a gas-aggregation sputter source in Ultra-High Vacuum conditions [1]. A vapour of Fe is produced through Ar ions impacting on the Fe target, and the Fe atoms then aggregate into clusters and they pass into the next chamber. Magnets are also utilized to focus the plasma at the surface of the Fe target.

Chamber 2: The Fe nanoparticles follow a pressure gradient created throughout the system. achieved by differential pumping.

Chamber 3: The Fe nanoparticles pass through a heated tubular crucible and become coated with the desired shell material. The shell thickness can be tuned with the temperature of the crucible.

Chamber 4: The Fe nanoparticles can be deposited onto TEM grids or also into water using a water jet and a target cooled with liquid nitrogen. The deposition chamber can be sealed off so that samples can be removed without the need to vent the whole system.

Core-shell Nanoparticles

Why core-shell nanoparticles?:

- Pure iron (Fe) has highest magnetic moment – i.e. has the highest performance capability of any pure element
- Pure Fe oxidises readily in air and water
- Pure Fe is toxic

A shell **protects and stabilises** a pure Fe core and makes it **biocompatible**.

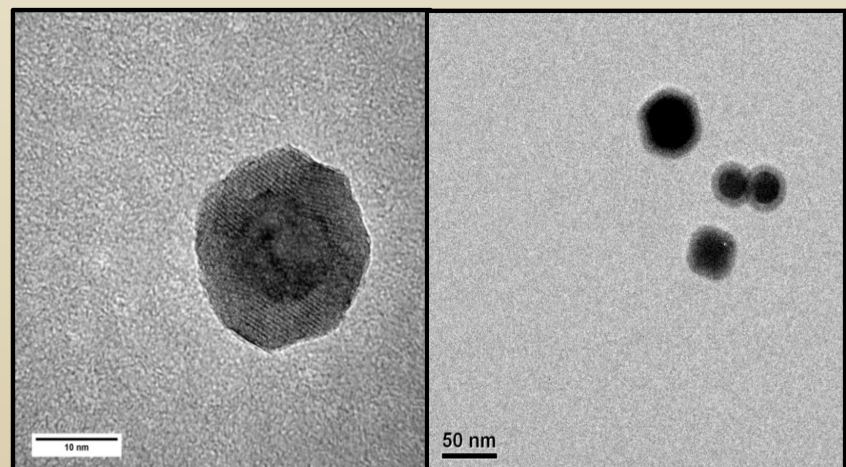


Figure 1: TEM images of suspected aluminium coated Fe nanoparticles produced using the gas-phase synthesis method explained above. It has been shown that the heating anneals the nanoparticles and changes their shapes and properties. [2]

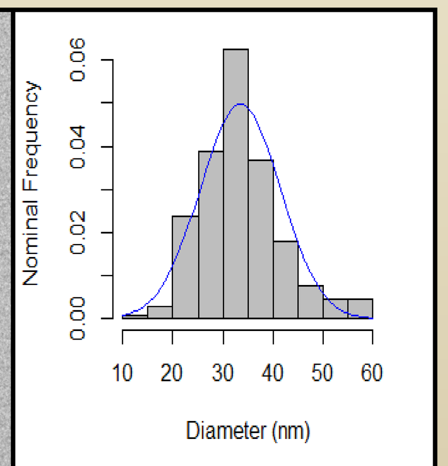
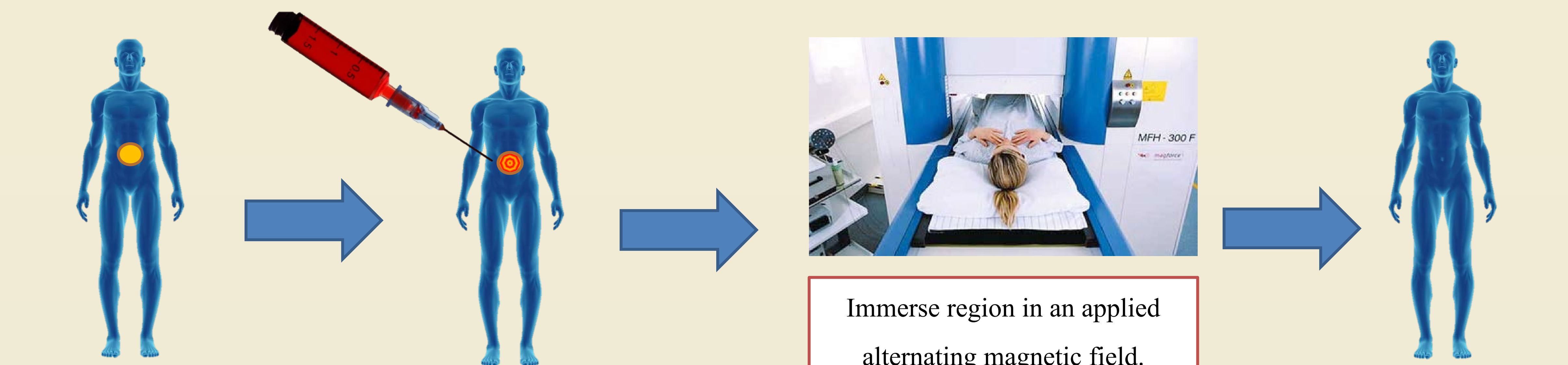


Figure 2: Size distribution of the nanoparticles as measured from TEM images (left). The mean diameter for these samples is 34 nm.

Magnetic Nanoparticle Hyperthermia

Magnetic Nanoparticle Hyperthermia (MNH) uses magnetic nanoparticles to produce heat. This used to raise the temperature of cells up to ~42°C promoting cell death. This treatment could potentially eradicate the severe side effects found with chemotherapy and radiotherapy due to its targeted nature. Clinical trials in Berlin (Magforce) use iron-oxide nanoparticles for treatments of brain and prostate cancers with promising results. Our nanoparticles show encouraging results in the preliminary experiments conducted – see figure 4 - and we hope to produce the highest performing nanoparticles, increasing the chances of MNH being used as an effective stand alone treatment for cancers. The MNH treatment process is outlined briefly below. It is worth noting this is only one application of magnetic nanoparticles in medicine, others include contrast agents in MRI, use as a tracer in a new imaging system, Magnetic Particle Imaging (MPI), and targeted drug delivery.

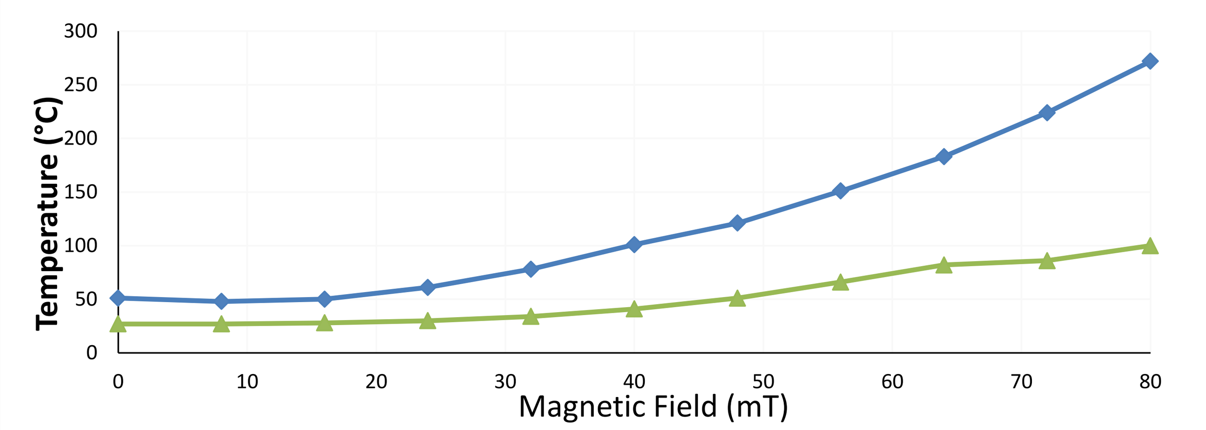


Tumour located in patient (orange circle)

Inject nanoparticles into affected area

Immerse region in an applied alternating magnetic field. Nanoparticles heat cells, promoting cell death.

Tumour killed



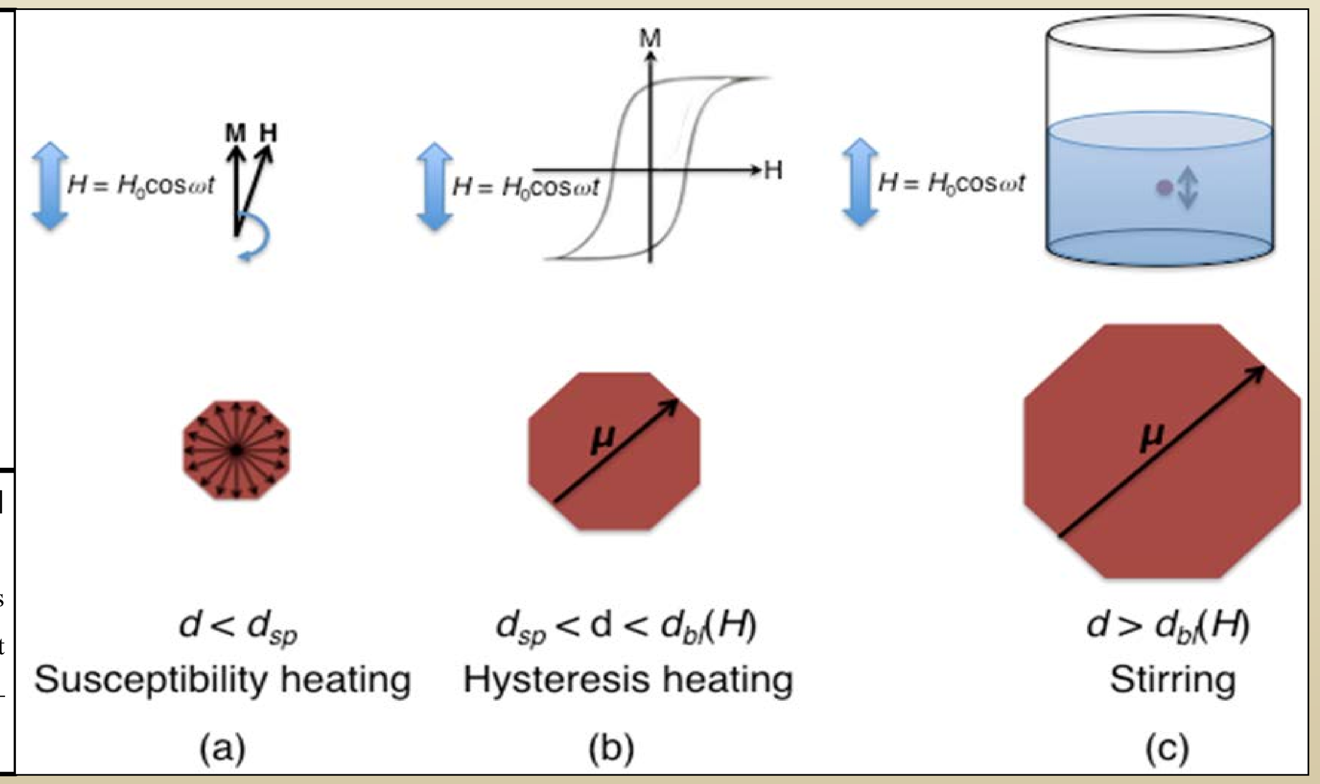


Figure 3 (right): Mechanisms of magnetic nanoparticle hyperthermia (MNH) dependant on particle size. See [3] for in depth explanation of these three mechanisms. Image from [4].

Figure 4 (above): Comparison between each pure silver, (Ag, green triangles) and iron (Fe) nanoparticles embedded in Ag matrices (blue diamonds). The temperatures should not be taken at face value due to significant eddy current heating in the sample. This experiment is currently being repeated with an insulating matrix – silicon oxide (SiO).

References

[1] Baker S. et al., 2000 [2] Aktas S., et al., 2015 [3] Vallejo-Fernandez G., et al., 2013 [4] Binns, 2014