Polymer Superparamagnetic Iron Oxide Nanorattles

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Research in the KCPC-Hawkett group

Within KCPC we have been doing collaborative and contract research for industry for over 22 years

Disperse Phase Polymerization and Coatings

ARC & DuluxGroup Australia

Microplastic removal from wastewater

- **PEGRAS**
- **NSSN**
- **NSW health**

Recycled HDPE materials and liquid waste

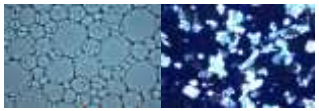
- **PEGRAS**
- **NSSN**
- **Visy**
- **Labelmakers**
- **Bega/Dairy Farmers**

Battery technology for energy storage

- **Gelion**
- **Nexeon**

The Hawkett Group

Explosive Emulsions for the Mining Industry



ARC & Dyno-Nobel Asia Pacific

Sterically stabilized nanoparticles for nano medicine

- **Sirtex Medical**
- **Ferronova**
- **Zeta Therapeutics**

Agrochemical Delivery Systems

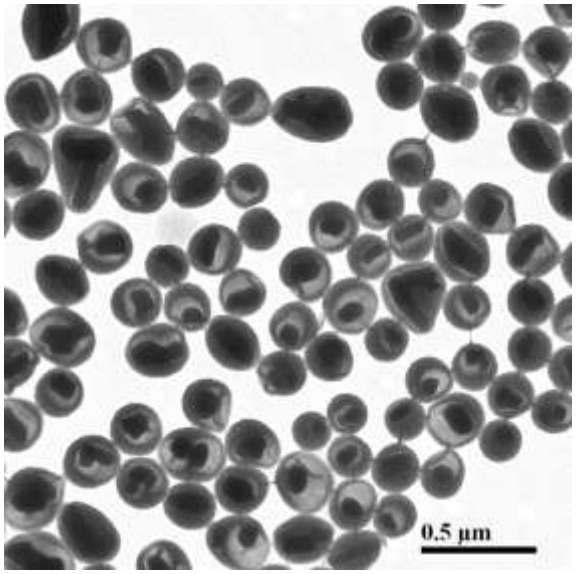
Syngenta Crop Protection

Ionic Liquid Ferrofluids for Space Propulsion

AOARD, US Air Force, Michigan Tech and Yale

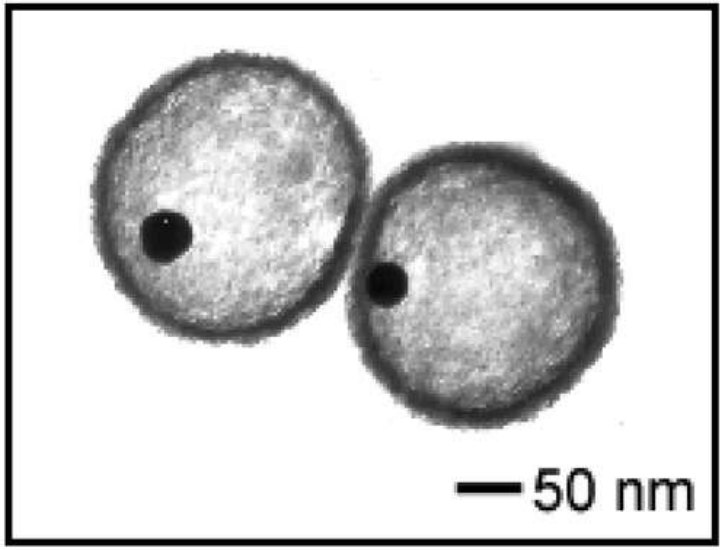
Nanorattles

- Nanoparticles consist of:
  - A hollow shell encapsulating
  - An (in)organic core
  - With a water/air layer/void separating the shell and the core



TiO_2 polymer nanorattles

Journal of Polymer Science Part A:
Polymer Chemistry 50 (2), 346-352

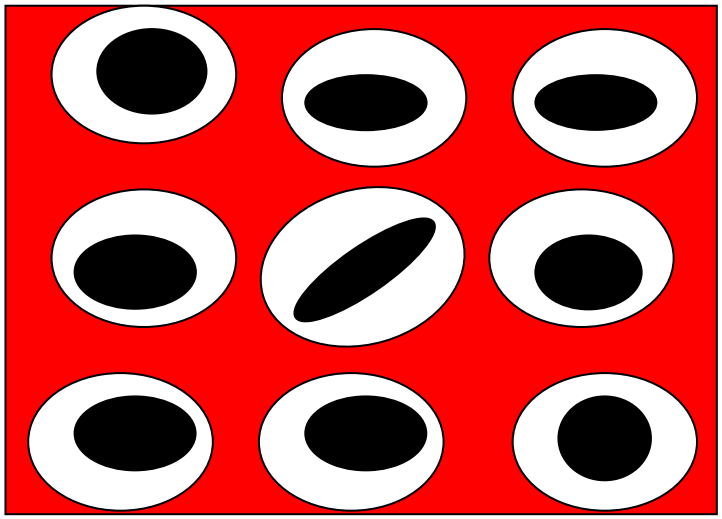


Gold polymer nanorattles

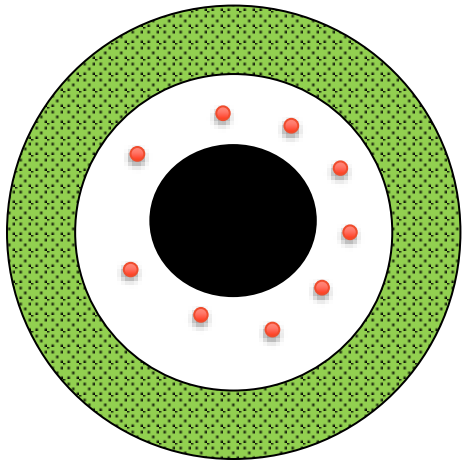
J. Am. Chem. Soc. 2003, 125, 9, 2384–2385

Potential applications

- Paint and coating: enhance opacity of titanium dioxide in paint films, resulting up to 40% pigment saving
- Potential applications:
  - Drug delivery: space between the shell and core can be used to store drugs, especially anti-cancer drugs
  - Catalysis/battery: Adv. Mater.2008,20,3987–4019



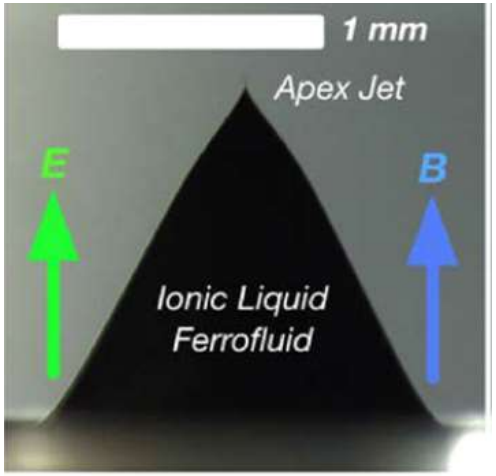
Nanorattles in paint film to enhance pigment light scattering

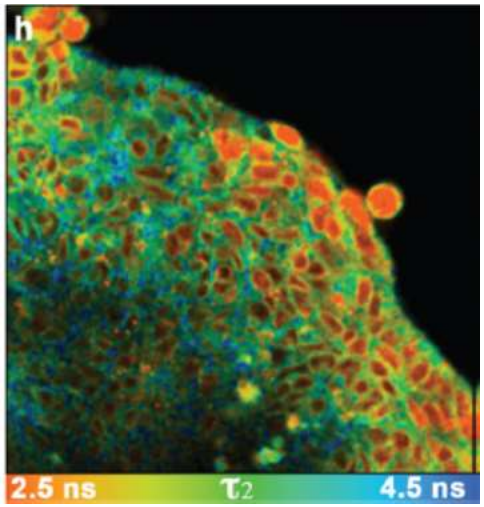


Drug loaded nanorattles

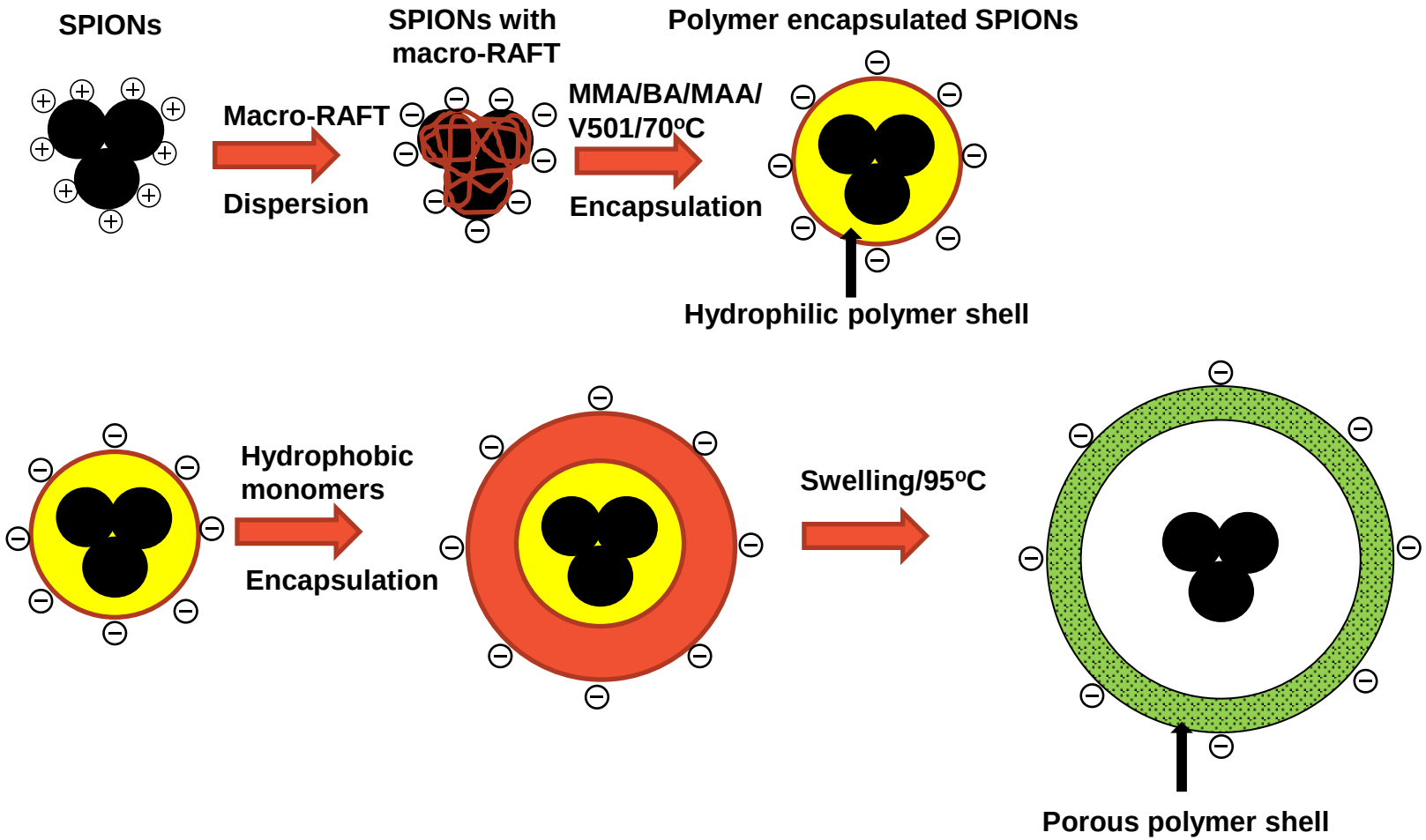
SPION core

- Superparamagnetic iron oxide nanoparticles (SPIONs): display magnetic property only under the influence of magnetic fields
- Iron oxides:
  - Magnetite: Fe_3O_4
  - Maghemite: Fe_2O_3
  - Iron oxides doped with other metal oxides
- They have been used in a number of biomedical applications such as:
  - Cell labeling
  - Hyperthermia
  - Drug delivery
- We wanted to make iron oxide nanorattles:
  - To cover the IP that we launched with Dulux
  - Sirtex (customer at the time) was interested in SPIONs
  - SPIONs are ideal for targeted delivery

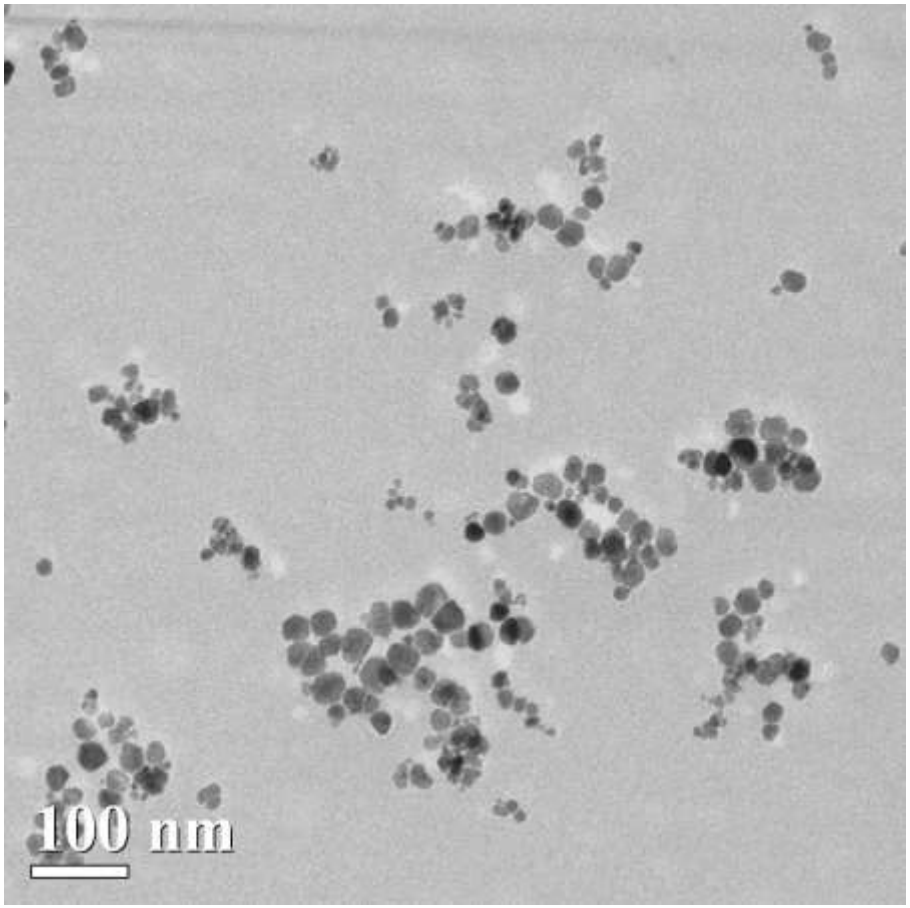


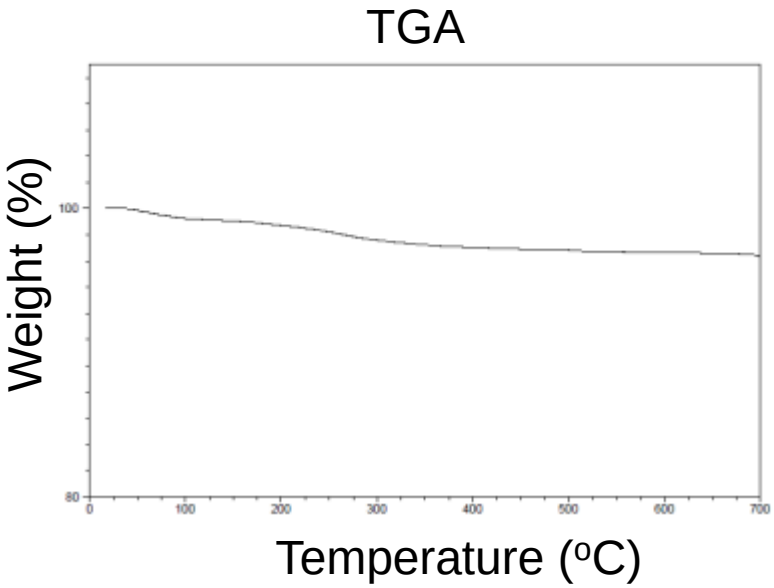


SPION nanorattle synthesis via RAFT emulsion polymerisation



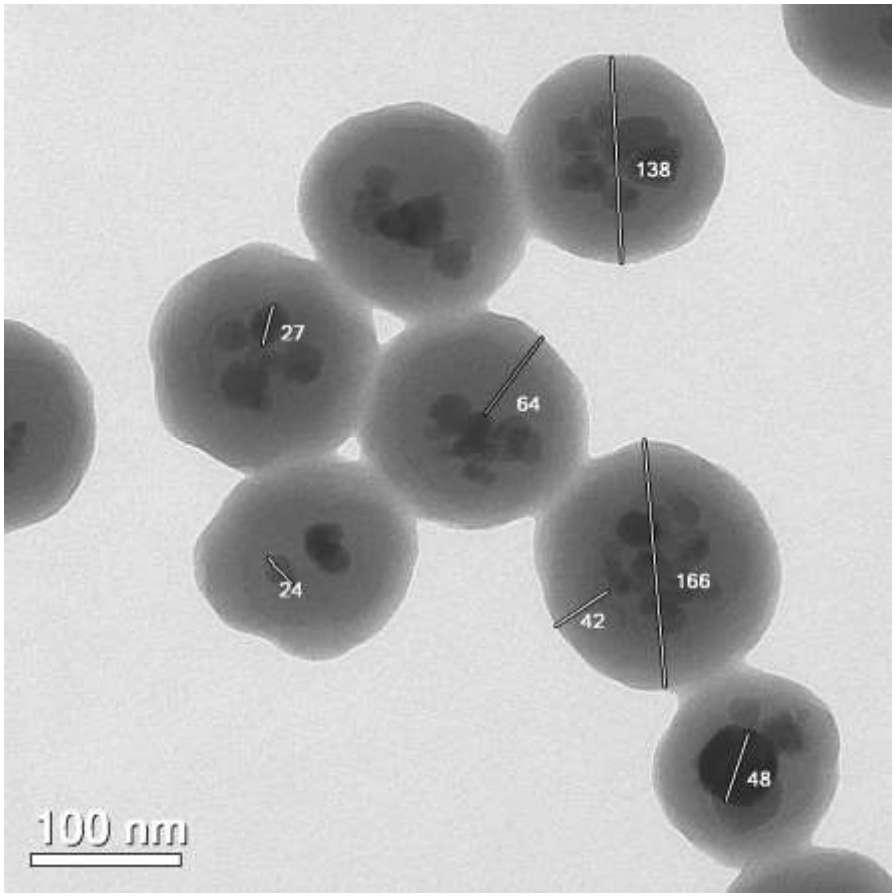
SPIONs

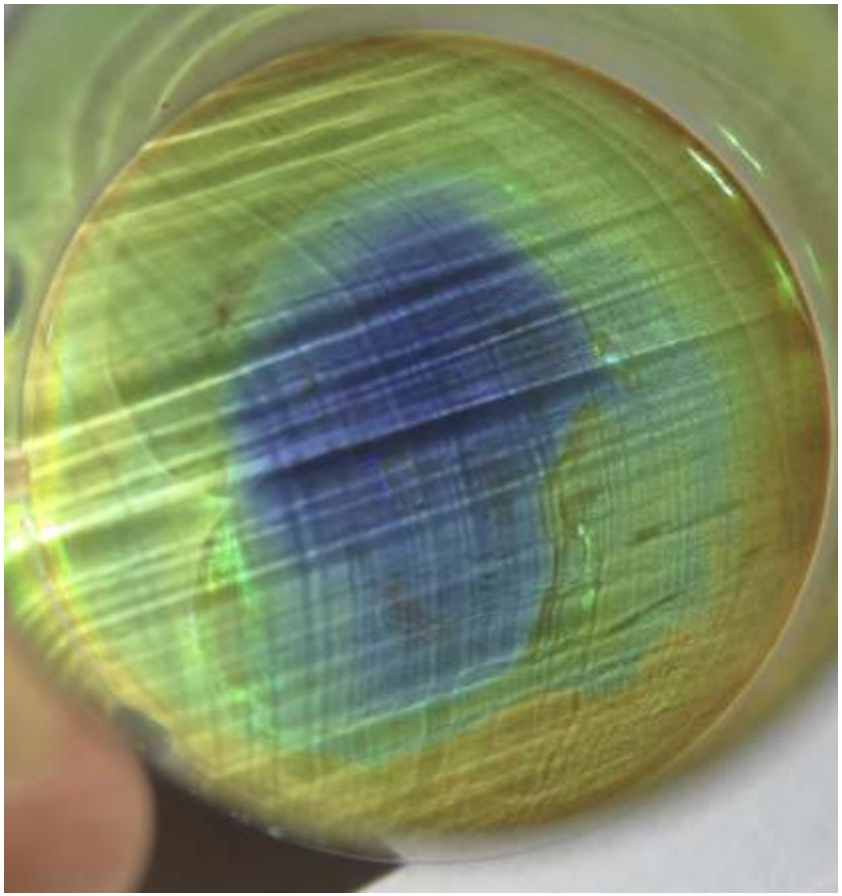




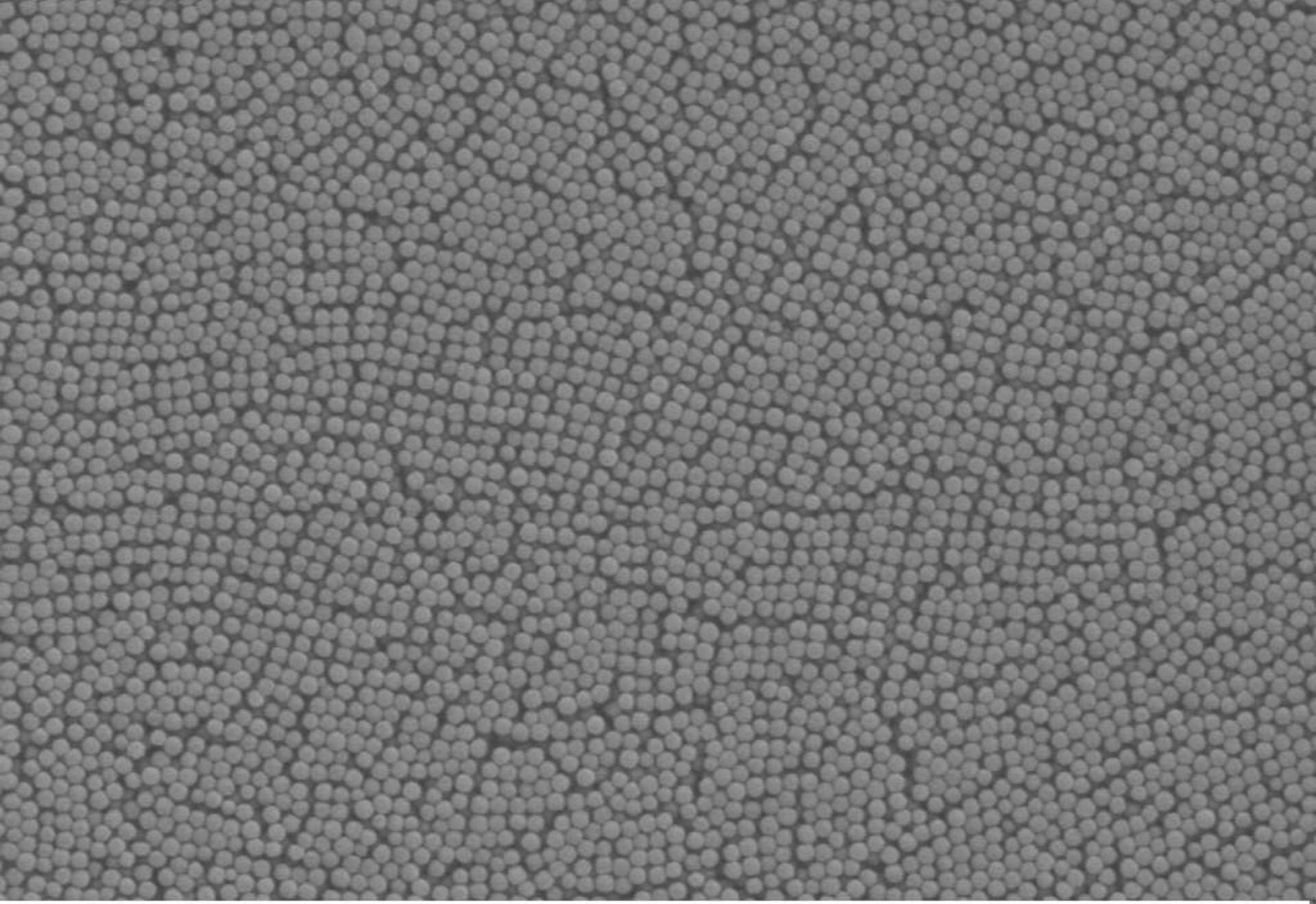
- Sirtex iron oxide nanoparticles are 10-50 nm in diameter with strong magnetic property
- TGA: no organic stabilizer

Polymer encapsulated SPIONs (before swelling)





- 150 nm on average, 55 nm shell thickness
- Monodisperse and opalescence


1 µm
WD = 7.0 mm
EHT = 5.00 kV
Mag = 10.00 K X
Signal A = SE2
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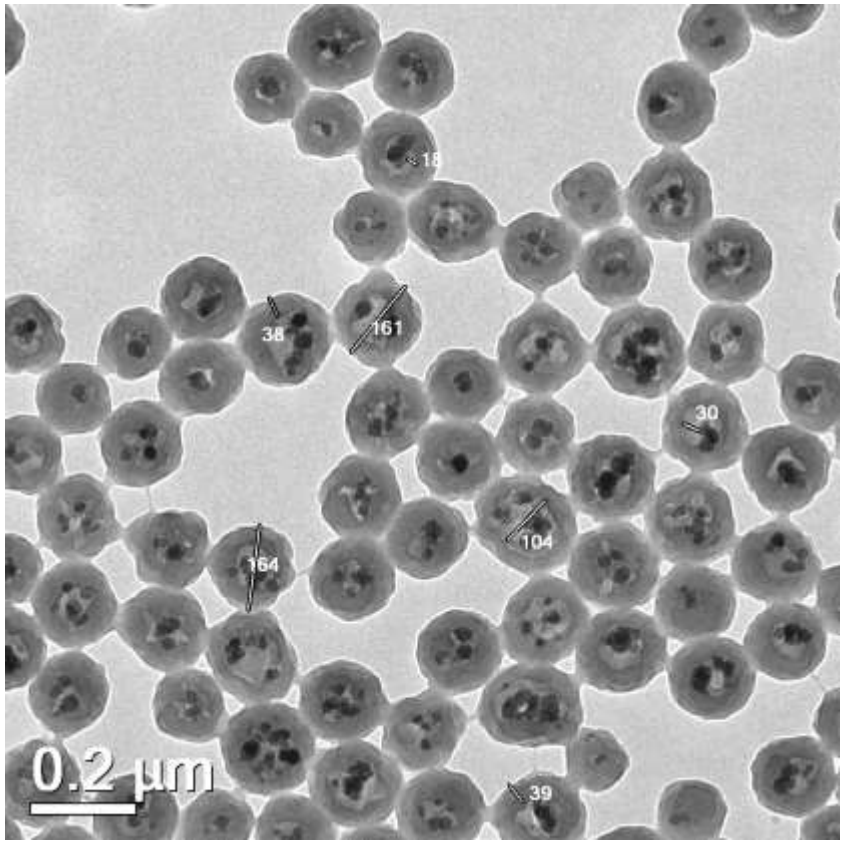
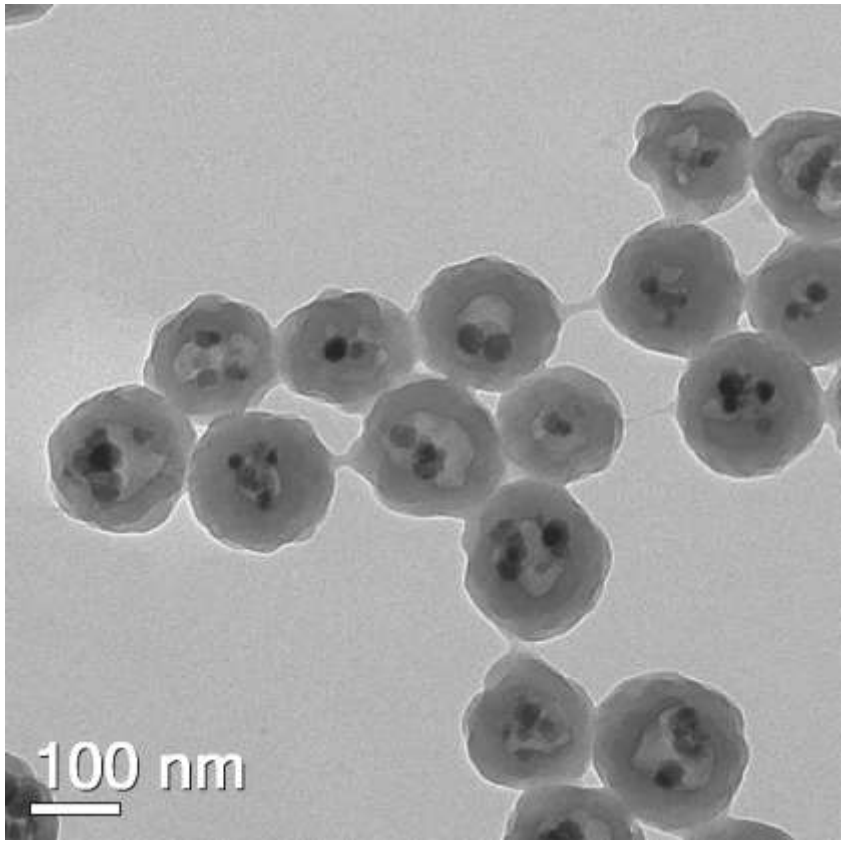
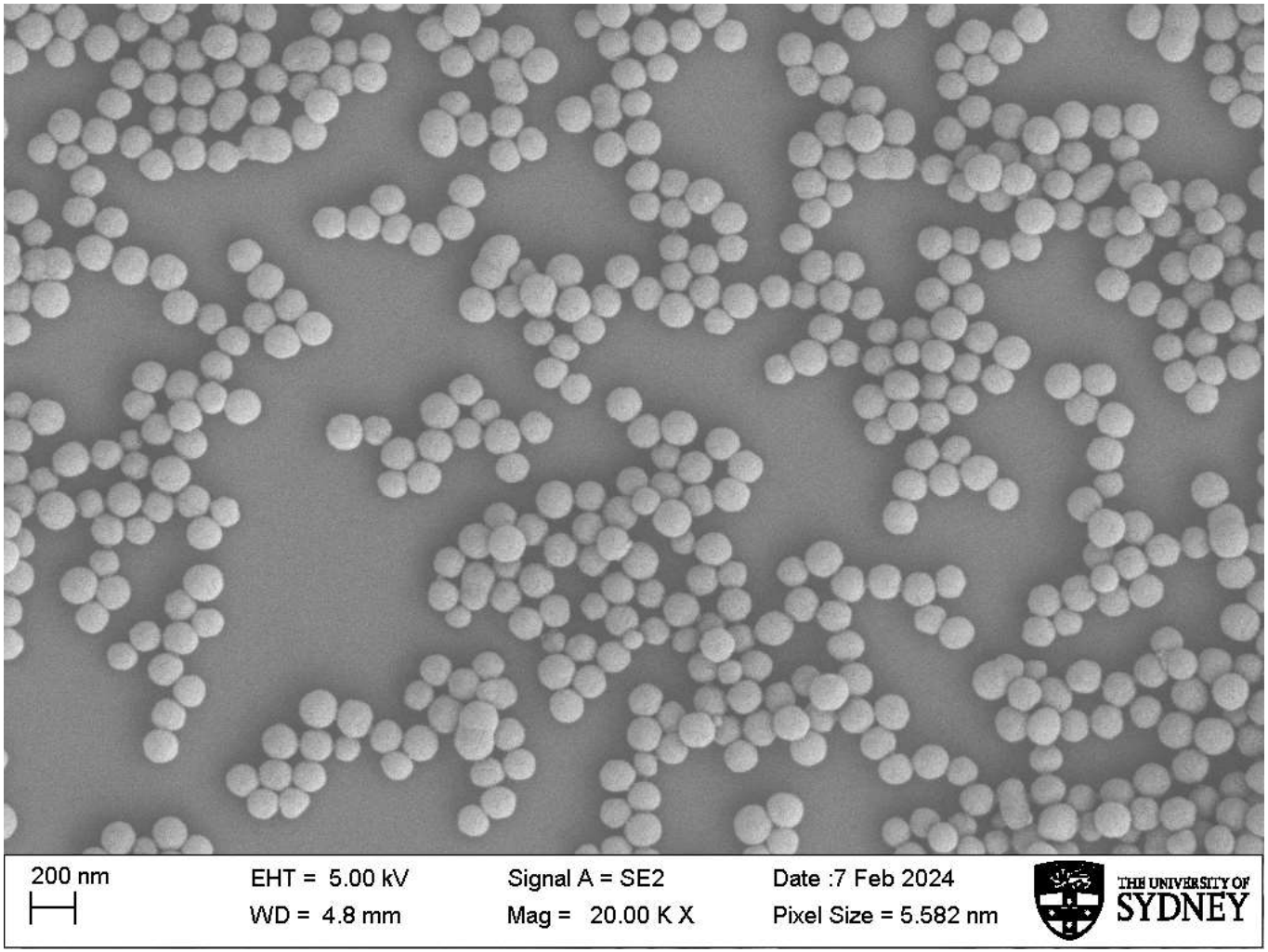
SPION polymer nanorattles (TEM)





- 185 nm on average (DLS, 0.004 PDI)
- 40 nm shell thickness
- 50-100 nm voids containing iron oxide particles

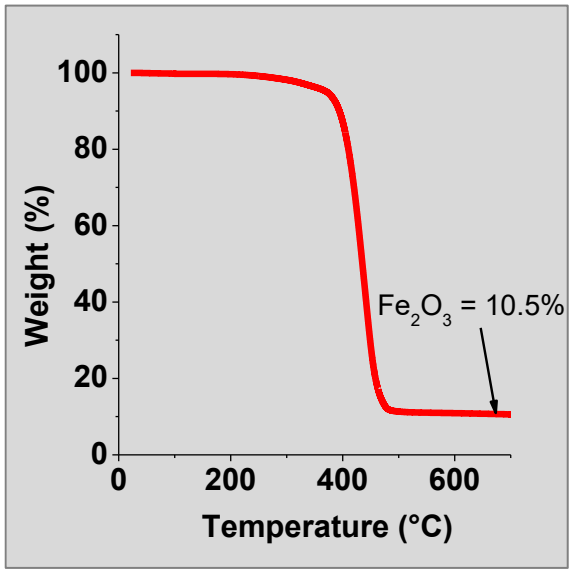
SPION polymer nanorattles (SEM)



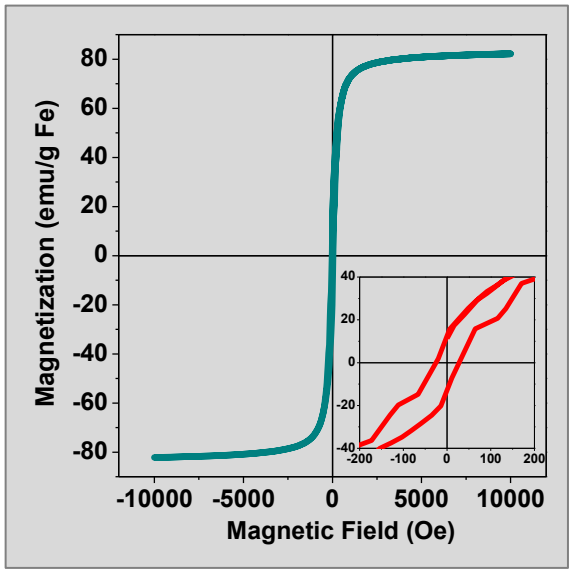
– Still maintain shell integrity: no broken shells

SPION nanorattles – TGA and magnetism

TGA: Fe_2O_3 = 10.5%



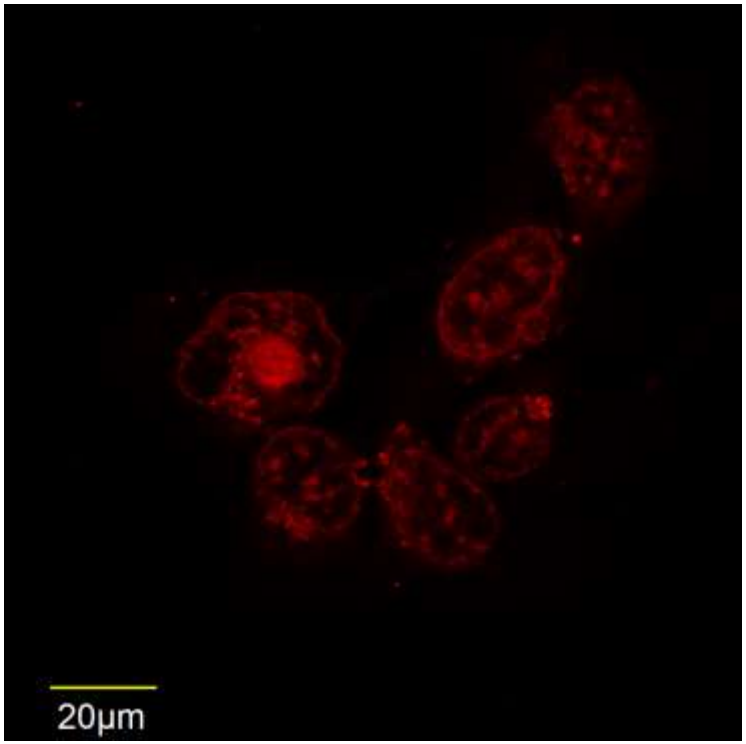
M_s 80 emu/g Fe



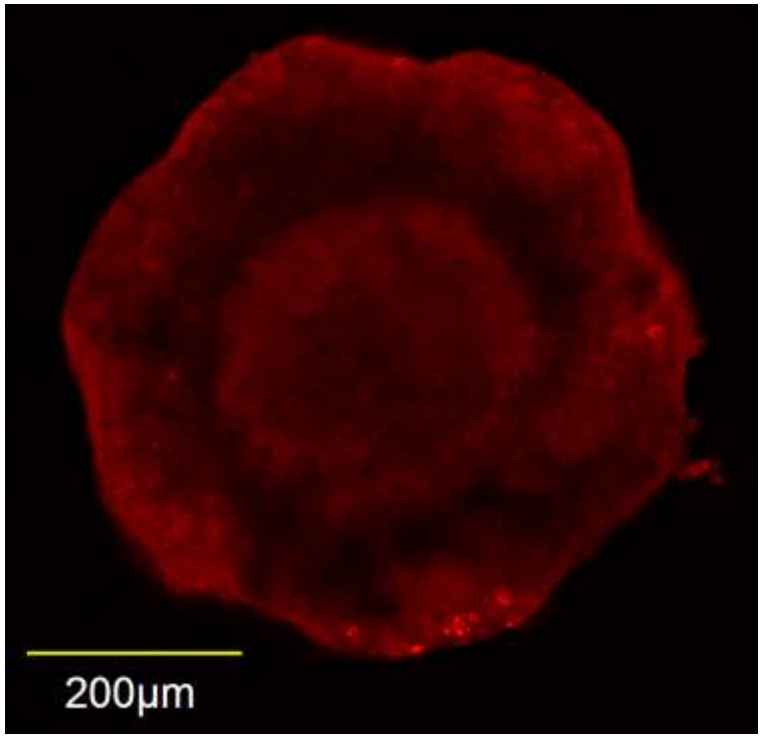
- Contain mostly polymer (89.5wt.%)
- Maintain superparamagnetic property of the original SPIONs

Dr Nguyen Pham: Penetration of Doxorobucine loaded nanorattles into 2D DLD-1 cancer cells and 3D DLD-1 spheroid

DLD-1 monolayer dosed with Dox-NRs (1uM as Dox) for 24h



DLD-1 spheroids were dosed with Dox-NRs (1uM as Dox) for 48h



Conclusions

- Iron oxide polymer nanorattle synthesis by polymer encapsulation of pigment using RAFT
- 185 nm in size with 50-100 nm voids containing SPIONs
- Monodisperse and superparamagnetic
- Doxorubicine loaded nanorattles could be taken up by cancer cells and penetrate 3D spheroid

Acknowledgments

- A. Professor Brian Hawkett, Prof. Chiara Neto, Prof. Greg Warr
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- Sirtex and Dr Steve Jones
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- ACMM
- KCPC members