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Numerical Investigation of Nanoparticle Formation in the Inductively Coupled Plasma

Korea Institute of Materials
and Science

2021.05.20

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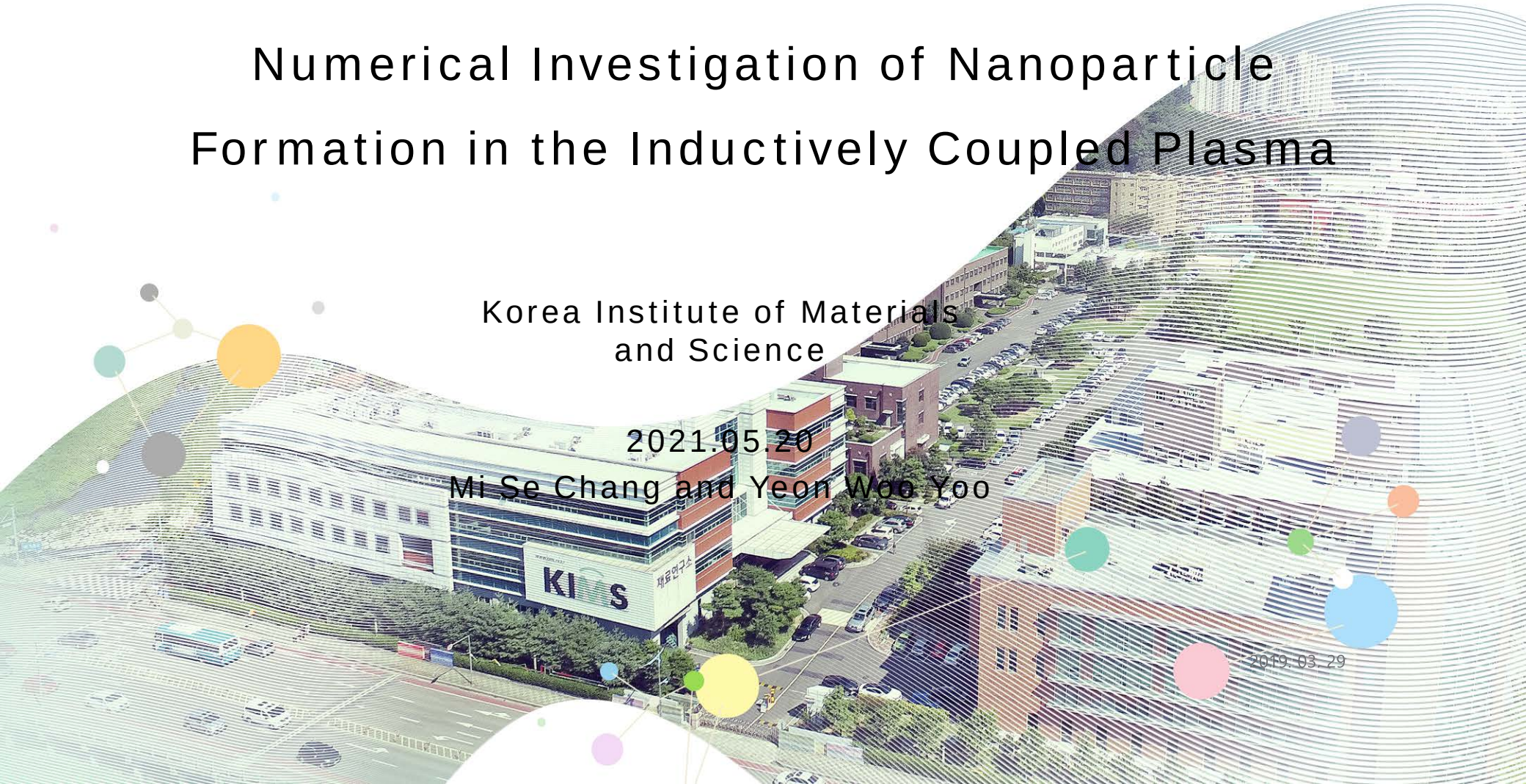


2019. 03. 29

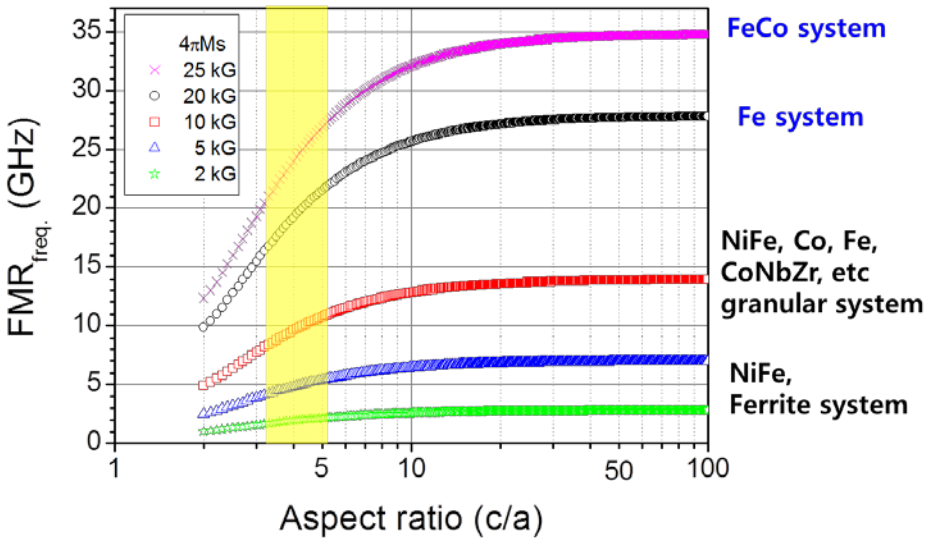
Development of magnetic particles with high permeability

❑ When designing a new magnetic material intended for broadband electromagnetic wave absorbing material (EWAM) properties, the following conditions should be met:

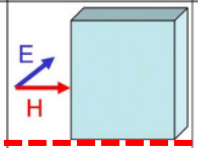
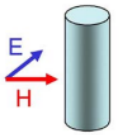
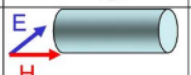
(1) High saturation magnetization

(2) Structural anisotropy for higher magnetic anisotropy

(3) Modulated permittivity for impedance matching



Change in FMR according to the saturation magnetic flux density and aspect ratio of magnetic particles

inclusion type	sketch	$A(ka)$	2nd order approx.
plate		$\frac{\tan(ka)}{ka}$	$1+\frac{(ka)^2}{3}$
cylinder ⊥H		$\frac{J_1(ka)}{ka.J_0(ka)-J_1(ka)}$	$1+\frac{(ka)^2}{4}$
cylinder // H		$\frac{2J_1(ka)}{ka.J_0(ka)}$	$1+\frac{(ka)^2}{8}$
sphere		$\frac{2(\tan(ka)-ka)}{ka+((ka)^2-1)\tan(ka)}$	$1+\frac{(ka)^2}{10}$

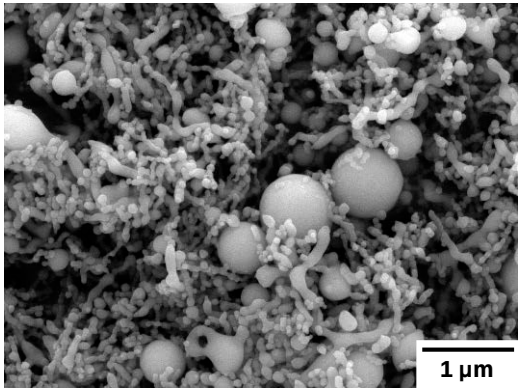
Improvement in permeability through powder shape control
(O. Acher et al., 2007)

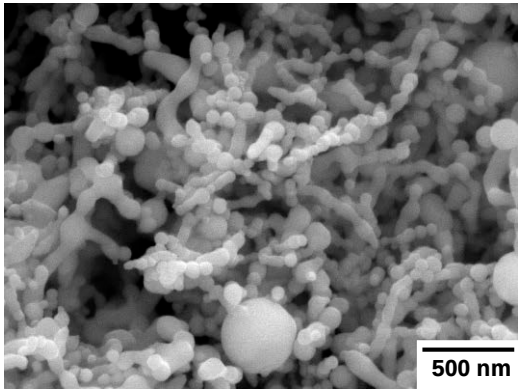
Development of magnetic particles with high permeability – thermal plasma synthesis

❑ Synthesis of magnetic nanorod particles through thermal plasma

- Thermal Plasma synthesis of Fe, FeCo nanoparticles (6000 ~ 15000 K)
- 1-dimensional nano-chained particles were successfully fabricated without need for templates or complex directional growth process.

Fe-Co nanorods





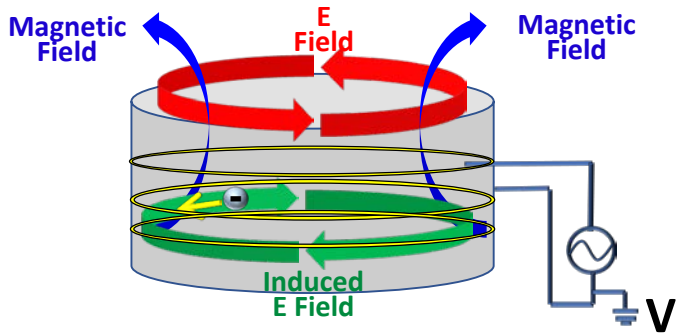
- How could varying the parameters of the plasma system affect the particle size of the FeCo nanorods?

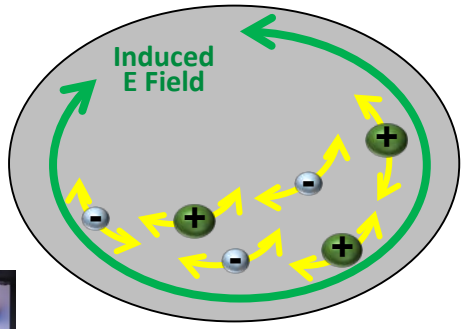
  → Numerical simulation needed

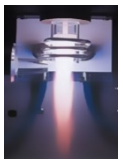
Thermal Plasma synthesis

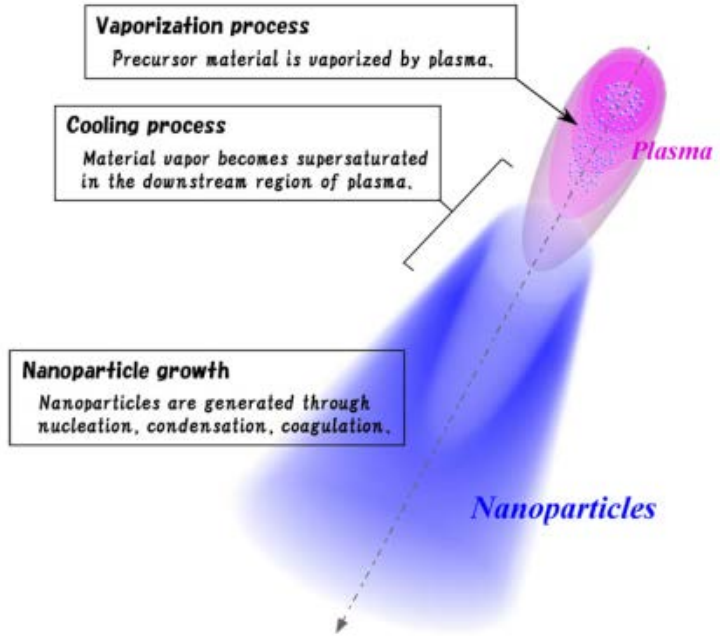
❑ Thermal Plasma

Inductively Coupled Plasma (ICP)





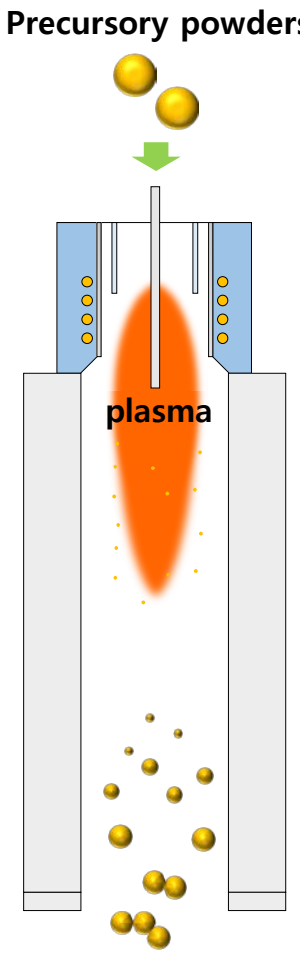




- **Thermal plasma**
  - Temperature: 6000 ~ 15000 K
    - Heavy particles possess temperature as high as 10^6~10^8 K while pressure is at atm.
- **Nanofabrication using RF-ICP**
  - Evaporation of precursor
  - Nanoparticle formation by condensation

Numerical investigation

❑ Numerical investigation of nanoparticle formation in ICP



← Inductively coupled thermal plasma modeling

- Conservation of mass
- Conservation of energy

← Behavior of powders in ICP

- Particle motion accelerated by plasma flow
- Heat transfer between plasma and particle

← Nanoparticle formation

- Saturation of vapor
- Nucleation and growth

Summary

- Tailoring the shape of magnetic nanoparticles to 1-dimensional nanomaterials and further tuning the length or the size of the nanochain can improve the magnetic response due to the anisotropic properties.

- Controlling the length or the size of the FeCo nanochain may be difficult due to numerous controlling parameters within the ICP system.

- Numerical investigation of ICP and formation of nanoparticle can predict size distribution of nanoparticles and aspect ratio of nanochain.

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Thank You