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Soft magnetic composites with enhanced performance and their key production technologies

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Background

Soft Magnetic Composites:

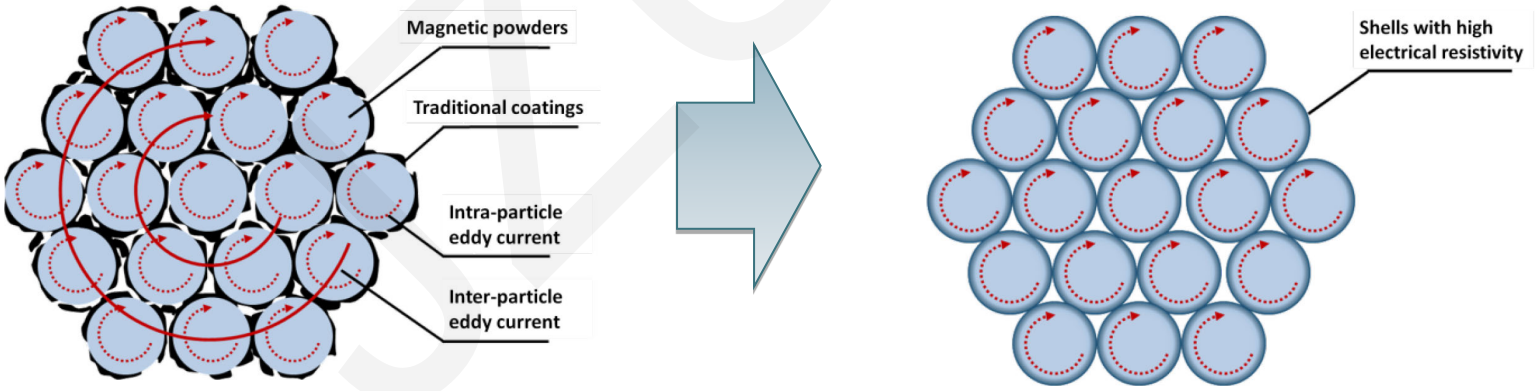
- Prepared by procedures including powder production, insulation coating, binding, compaction and annealing
- Fundamental components in the fields of energy, information, transportation and national defense
- Developing directions: high frequency, large power, energy saving and being electromagnetically compatible

Fig. 1 Typical soft magnetic composite products

SMCs with core-shell structure containing multiple soft magnetic phases

Reduction of the loss, mainly eddy current loss of the SMCs, is a worldwide issue

- **Original idea:** generating soft magnetic shells with large electrical resistivity surrounding the magnetic powders via chemical heat treatment



a. Traditional insulation coating b. Core-shell structure

Fig. 2 Core-shell structure with multiple soft magnetic phases significantly reduces the eddy current loss

SMCs with core-shell structure containing multiple soft magnetic phases

Research carried out：

- Kinetics and dynamics during chemical heat treatments
- Effects of the gas partial pressure, annealing temperature and reaction time on the morphology and thickness of shells as well as the interfacial structures
- Controllable growth of the shells

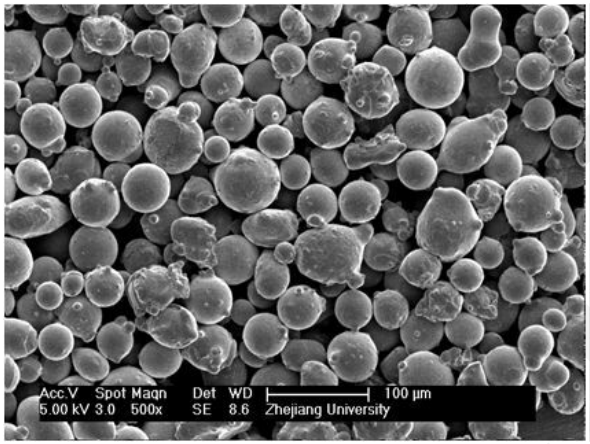
Core shell SMCs with multiple soft magnetic phases

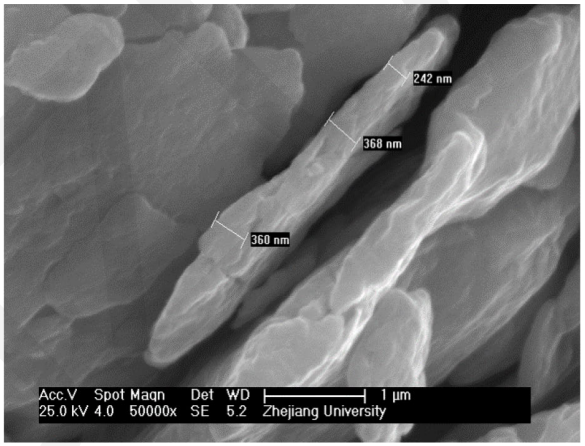
- Suppressing the eddy current loss
- Reducing magnetic dilution for enhanced performance
- Providing excellent adhesion of the shells for maintained stability during compaction and annealing

New magnetic alloy systems with enhanced properties

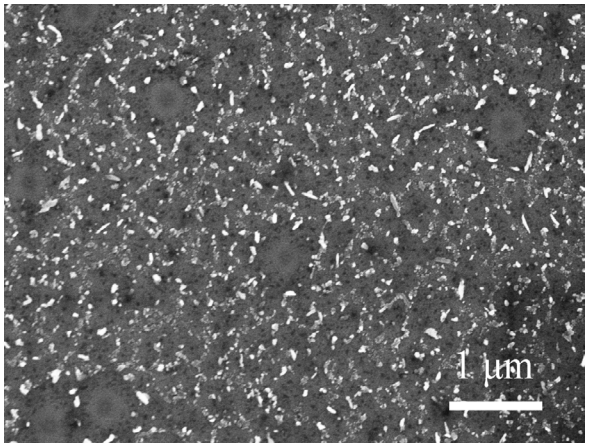
New magnetic alloy systems

- FeSiMe and FeNiMe based crystalline magnetic alloys
- FeCuNbTiSiB and FeNiAlSiB nanocrystalline magnetic alloys
- Optimizing traditional magnetic alloy systems such as MPP and Sendust, etc.





SEM images showing the spherical and flaky crystalline alloy powders



SEM image showing the growth of nanocrystals in the FeCuNbTiSiB alloy

Systematic integration of key production technologies

Systematic innovation and integration

- Improved the design of the key component of the atomization furnace
- BN-based refractory material used as the nozzle of the non-vacuum atomization furnace

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- Stable production of the magnetic powders
- Elongated lifetime of the nozzel

- Simulations of the heat distribution of the cooling system for metal spinning
- Pre-heat treatment for enhance brittleness of the alloy ribbons

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- Improved amorphorization of the alloy ribbons
- Powder production efficiency

- New organic-inorganic hybrid binders via in-situ growth of SiO_2 nanoparticles in epoxy-modified silicone resin

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- Enhanced mechanical properties, thermal stability and electrical resistance

Summary

- **Soft magnetic composites with core-shell structure**

- ➢ Soft magnetic composites with core-shell structure containing multiple soft magnetic phases
- ➢ New magnetic alloy systems with enhanced properties
- ➢ Systematic invention and integration of key production technologies

- Series of new soft magnetic composites with enhanced performance and low loss
- Large scale production and wide applications