

Application of Soft Magnetic Metal-Flake Composite Material to High Frequency Inductive Components

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■ Basic feature of FlakeComposite™

- General
- Application to 3D-mounted SMD inductors

■ New version of FlakeComposite™ with epoxy binder.

- Internal structure
- Magnetic performance
- Mechanical strength

■ Application to High Frequency Inductive Components

- Magnetic sheet for Wireless Power Transfer
- PCB Embedded Noise Suppression Concept

■ Summary

Products with Soft Magnetic Materials

EMC

Line filters (Nomal/Common/Dual mode)



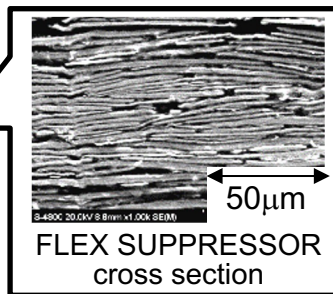
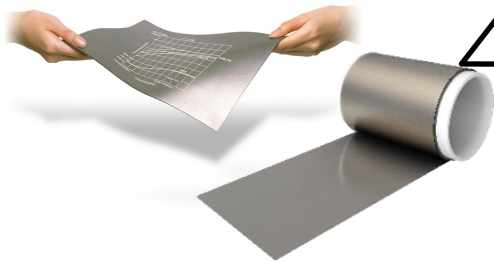
Noise filters



EMI cores



Noise suppression sheet (FLEX SUPPRESSOR®)



Inductors

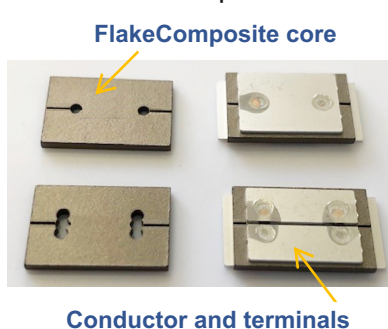
Chip inductors



Metal composite inductors (METCOM)



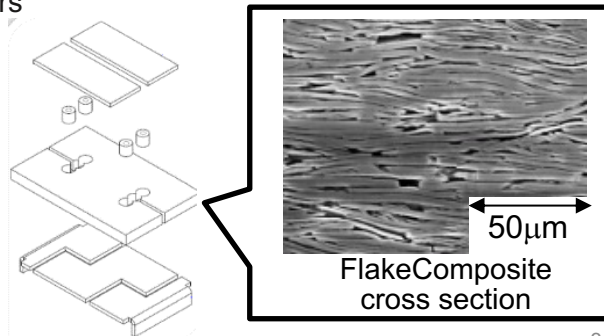
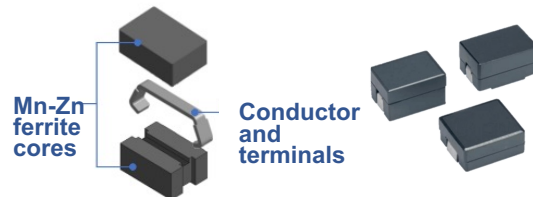
FlakeComposite inductors



Automotive reactors



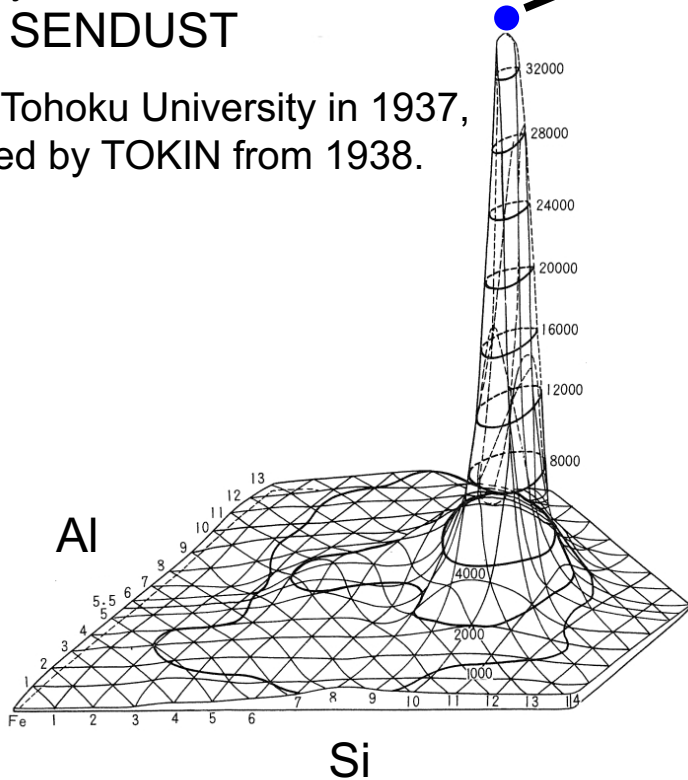
Ferrite inductors



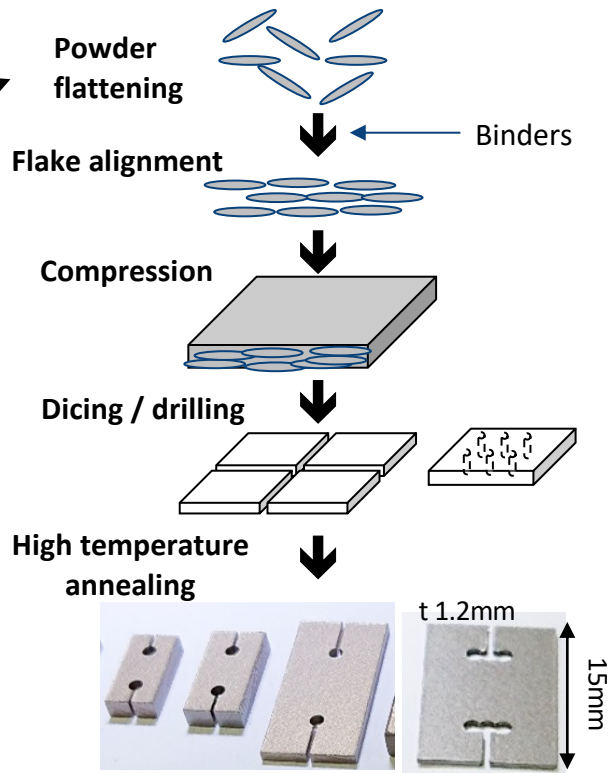
Structure of FlakeComposite

Alloy composition

- Steep permeability improvement in Fe-Si-Al alloy with Si9.5wt%、Al5.5wt%
➔ SENDUST
- Invented at Tohoku University in 1937, manufactured by TOKIN from 1938.

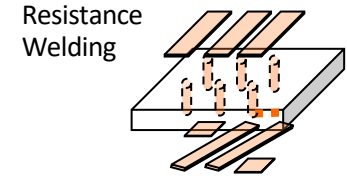
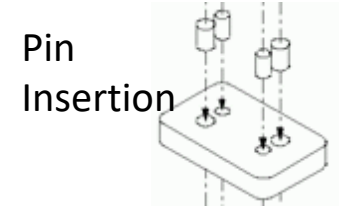
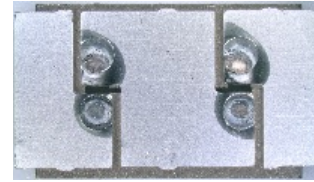
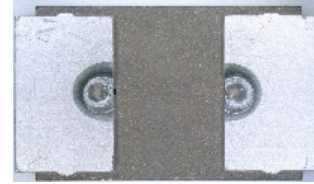
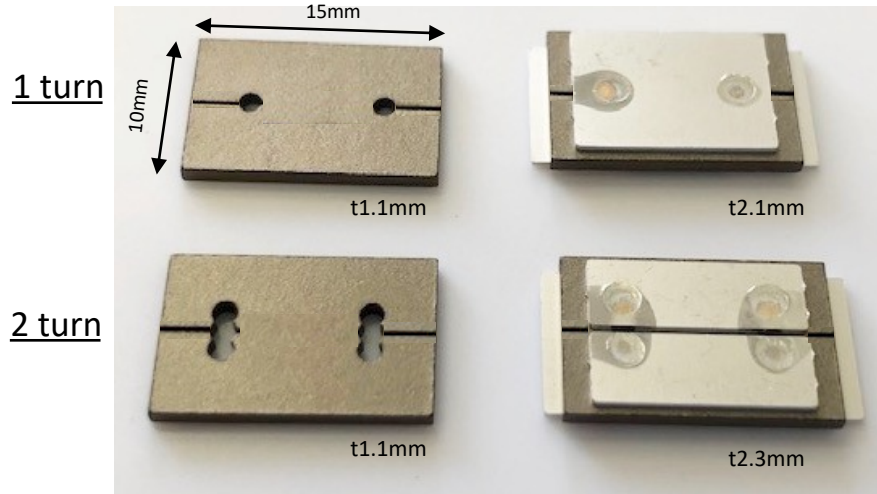


Fabrication process

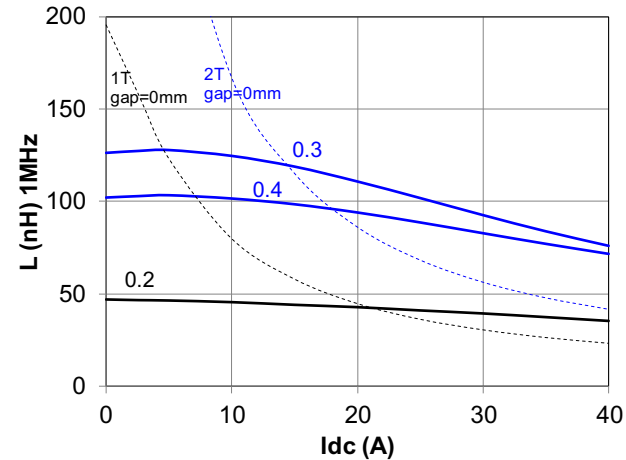


- Thin-plate shaped ($t \geq 0.1$) magnetic core is obtained.

SMD Inductor with FlakeComposite

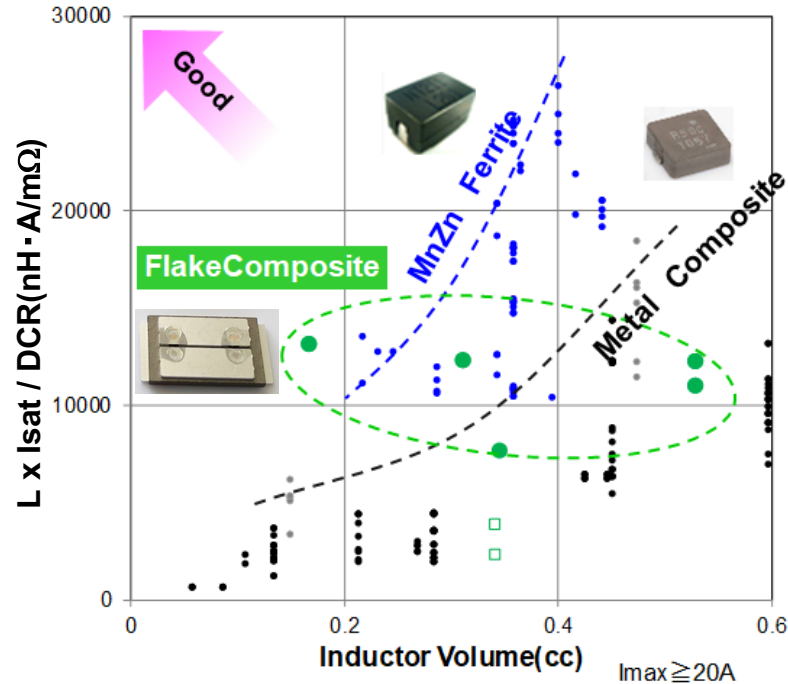


Turns	Air-gap (mm)	L_0 (nH)	$I_{sat} -20\%$ (A)	DCR (m Ω)
2	0.3	125	26	0.5
	0.4	100	31	
1	0.2	47	50	0.15

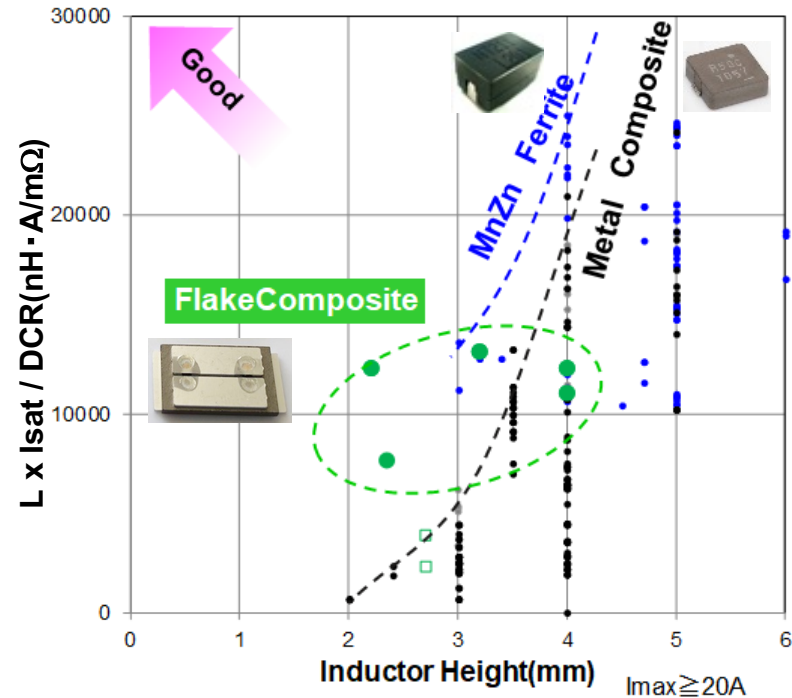


Inductor Performance Factor

$$\text{Performance factor} \equiv L \text{ (nH)} \times I_{\text{sat}} \text{ (A)} / \text{DCR (m}\Omega\text{)}$$



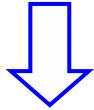
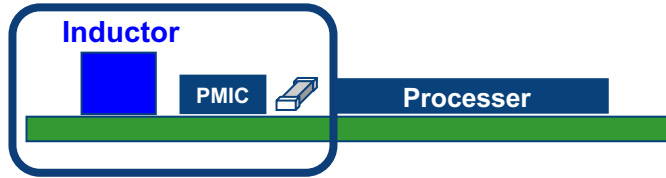
- Regarding inductor volume, advantage of FlakeComposite inductor is not prominent.



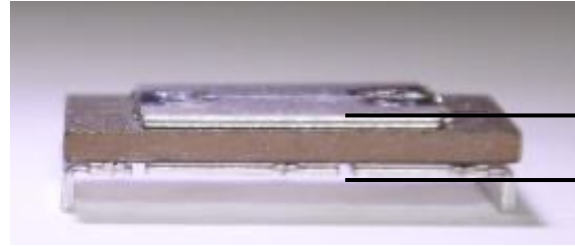
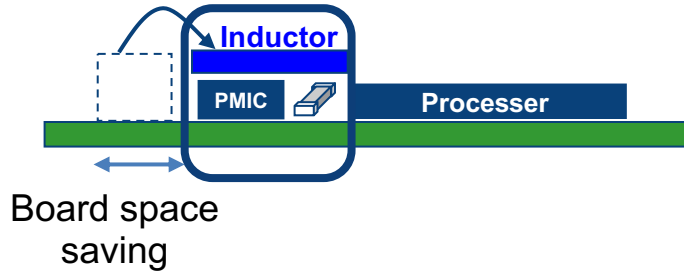
- Regarding inductor height, advantage of FlakeComposite inductor is prominent.

Application Example

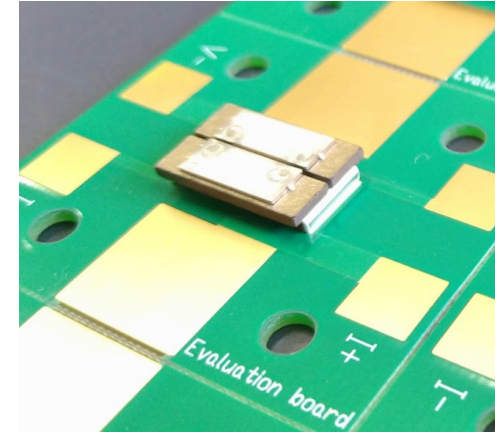
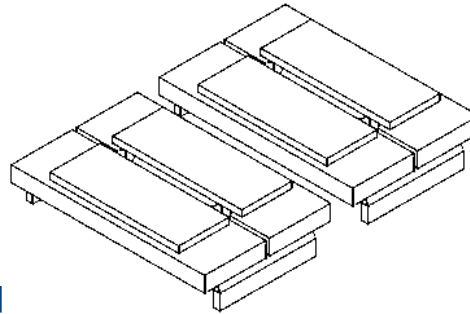
Conventional POL



3D mount POL

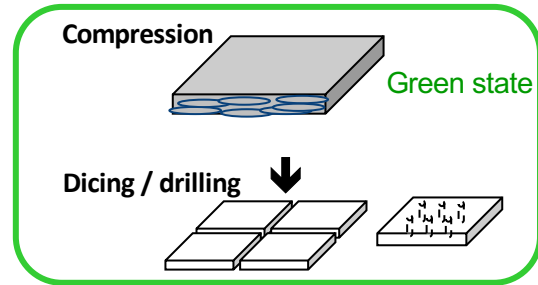
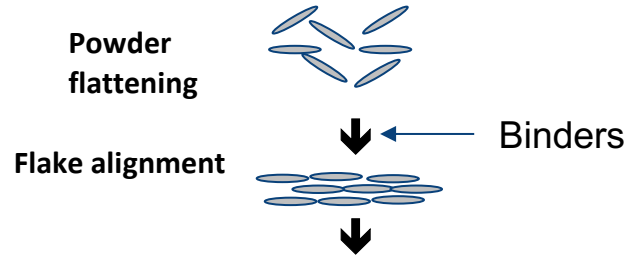


Inductor body
height
2.35 max

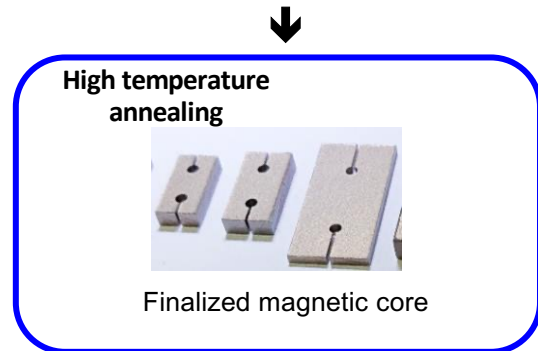


- 3D mount POL with FlakeComposite inductor has already been practical use.

Issue in Machinability



Machining :
easy



Machining :
difficult

- Shape forming is done before high temperature annealing.
- After the annealing, only the inorganic component is left inside the material, thus machining of the core by the customer is not available.
- To enable the machining by customer, new version of FlakeComposite has been developed as described below.

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■ New version of FlakeComposite™ with epoxy binder.

- Internal structure
- Magnetic performance
- Mechanical strength

■ Application to High Frequency Inductive Components

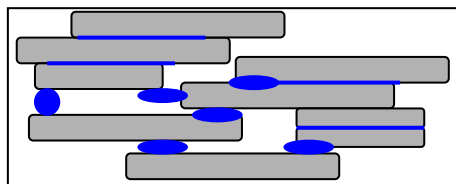
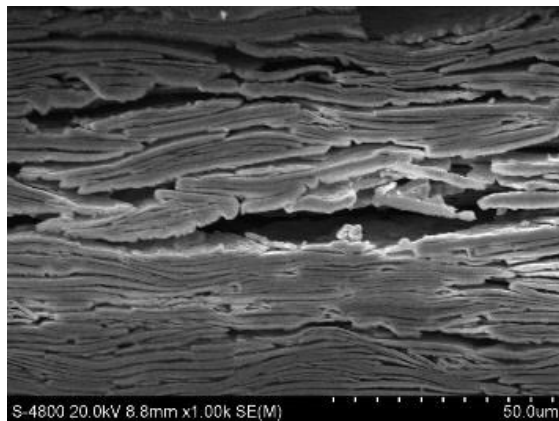
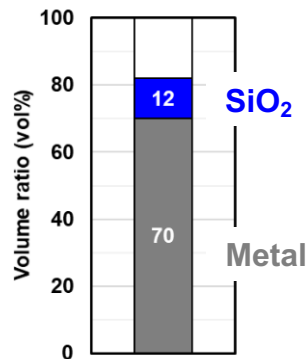
- Magnetic sheet for Wireless Power Transfer
- PCB Embedded Noise Suppression Concept

■ Summary

New version of FlakeComposite

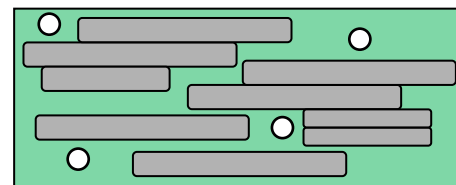
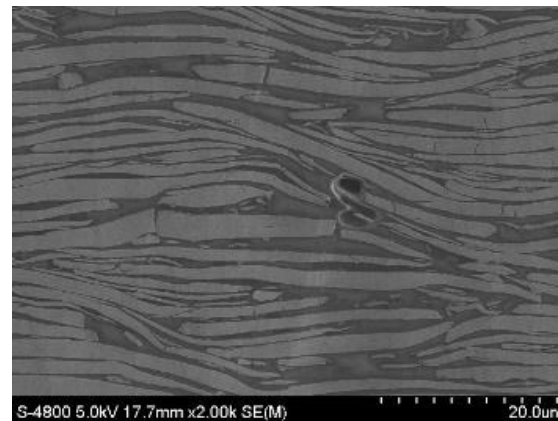
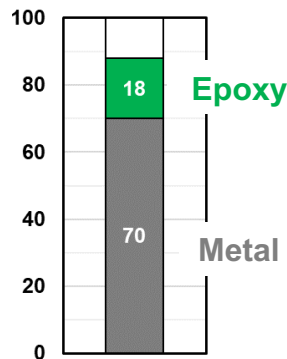
Current version

SiO₂ binder



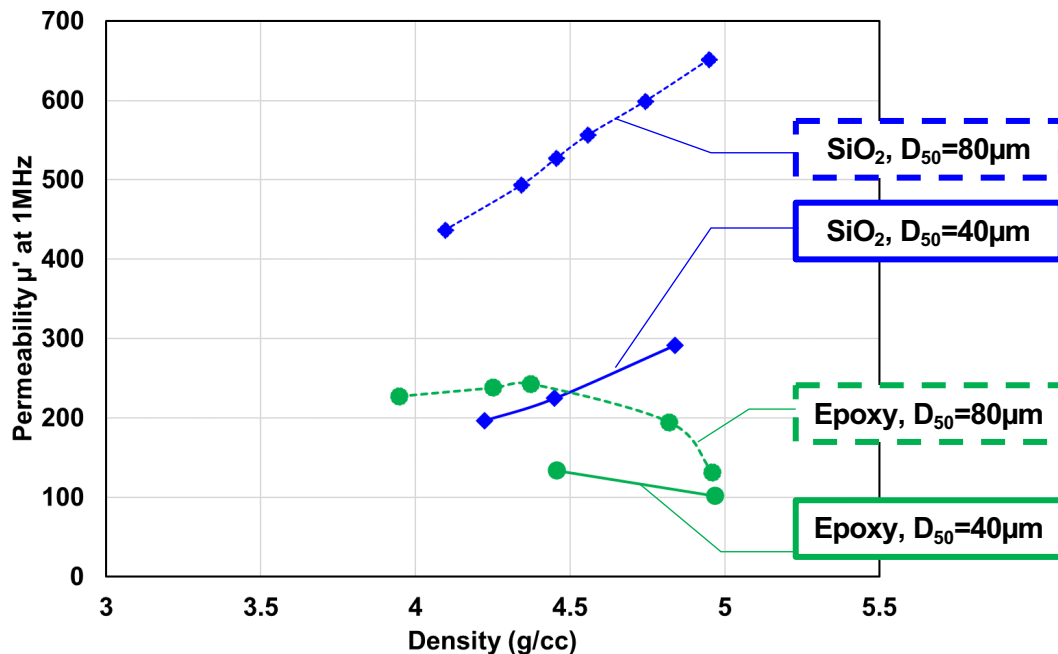
New version

Epoxy binder

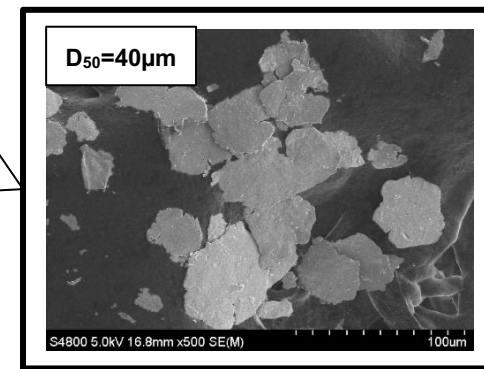
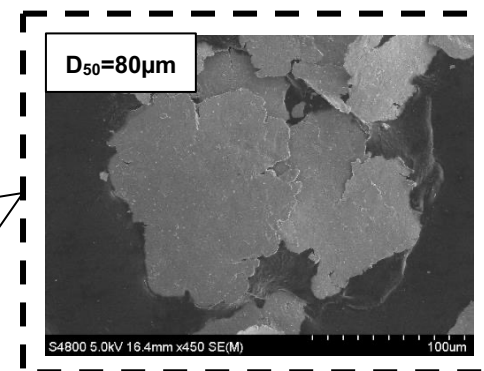


- Apply Epoxy binder instead of SiO₂ binder to enable machining by customer.

Permeability Trend in Each Version



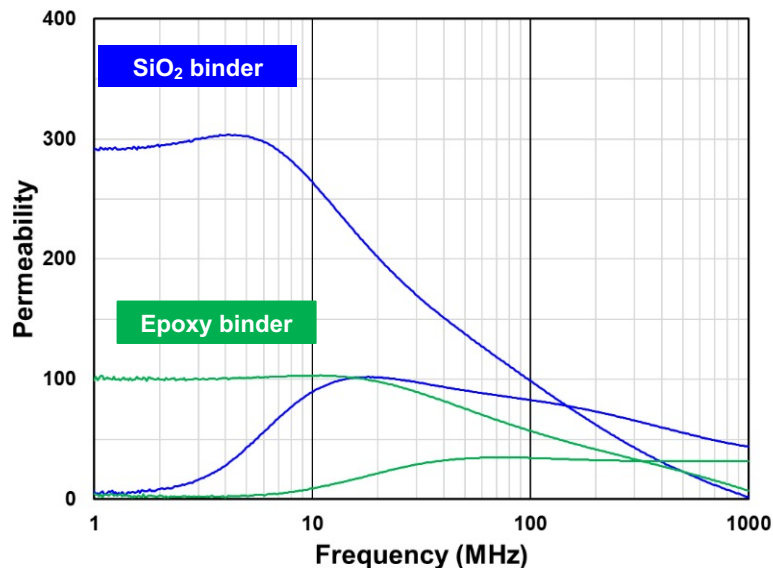
Flake size



- In **epoxy binder system**, permeability is lower comparing to **SiO₂ binder system**, but its permeability value of ≥ 100 is still much higher than conventional metal composite.

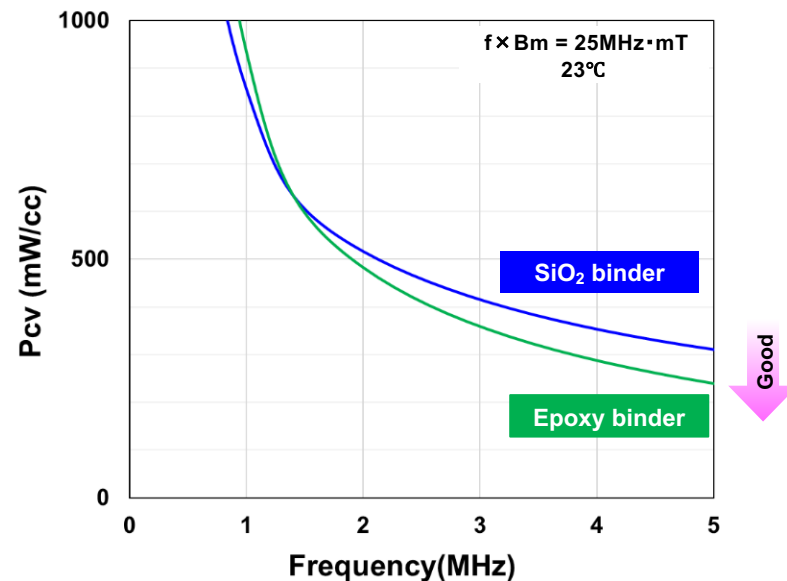
Permeability and Core loss vs Frequency ($D_{50}=40\mu\text{m}$ Flake case)

Permeability



- Lower permeability in epoxy binder system.

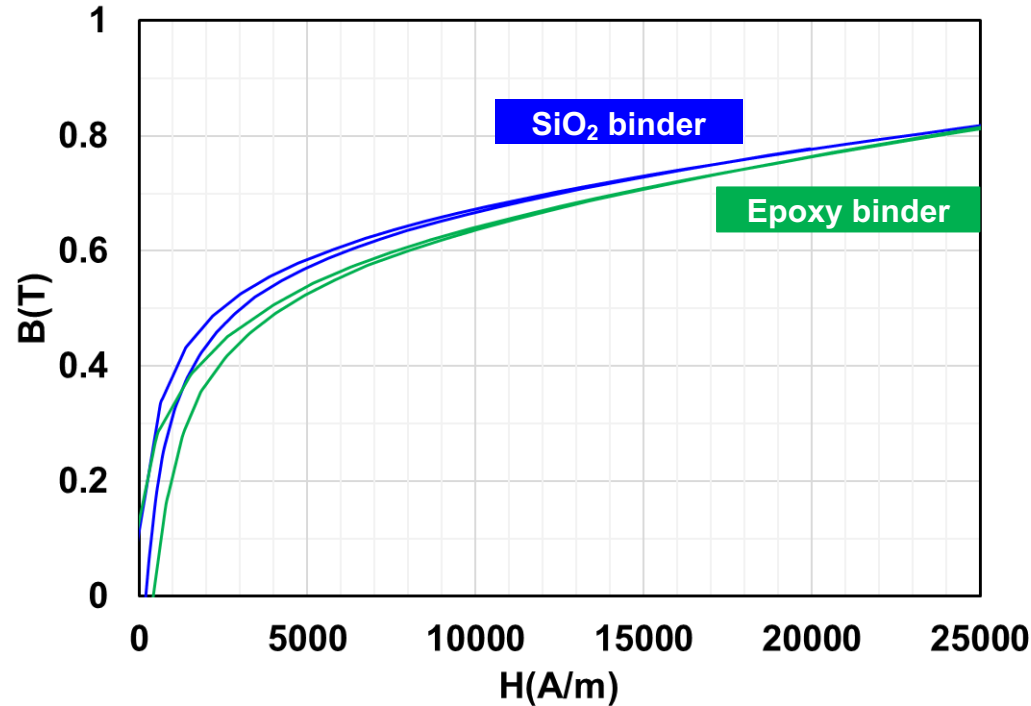
Core loss



- Core loss is not harmed by the change to epoxy binder system.

B-H Curve

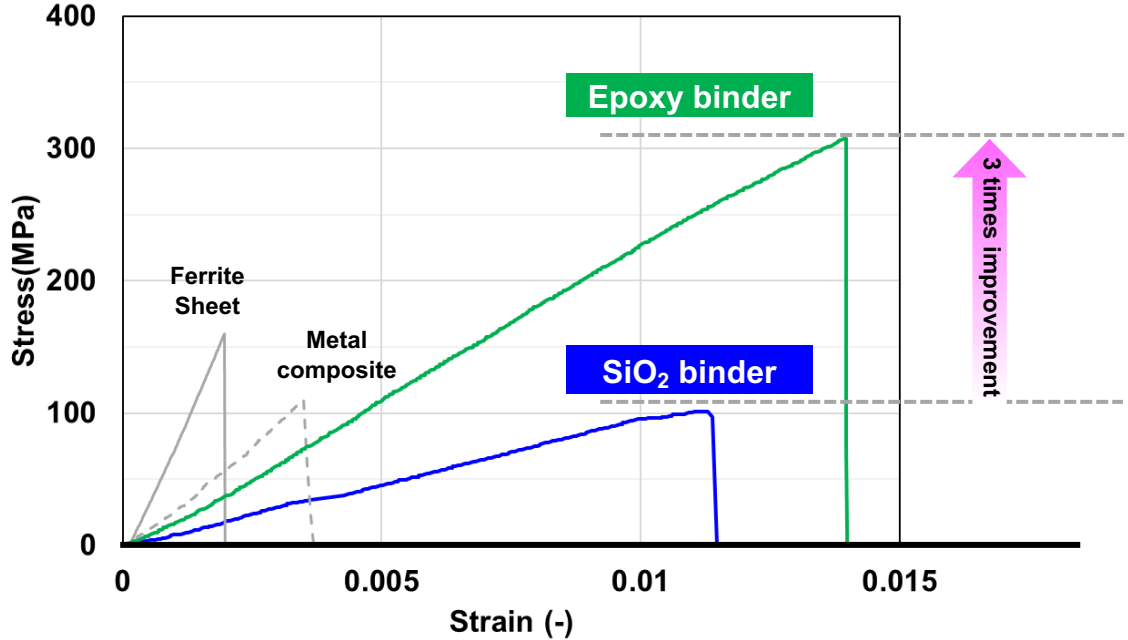
($D_{50}=40\mu\text{m}$ Flake case)



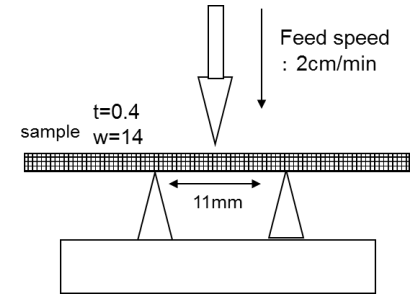
- The same metal content in each material, thus the saturated magnetic moment is same value.

Mechanical Strength

Stress-Strain curve

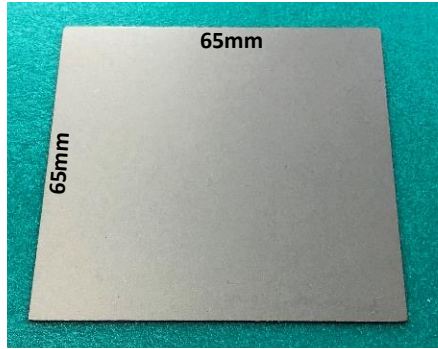


3-point bending test

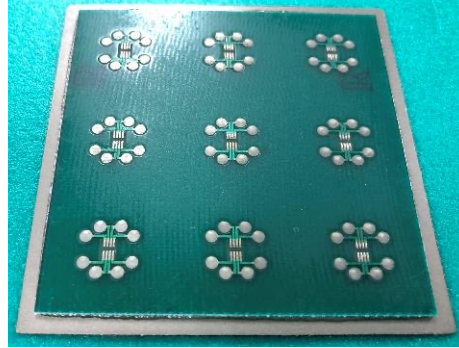


- **Epoxy binder** FlakeComposite is also superior in mechanical strength, which is higher than ferrite sheet or conventional metal composite.

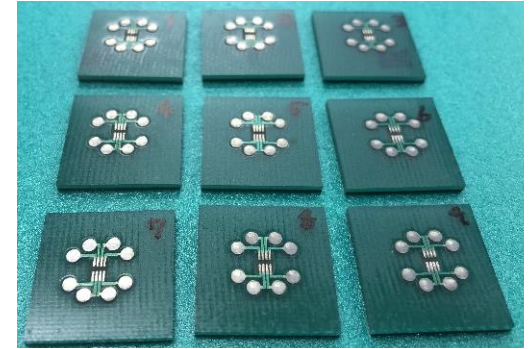
Example of Machining



- A sheet provided to customer.
- Thickness 500 μ m
(< 100 μ m is available)



- The sheet is attached on a PCB board.



- Integrated PCB and FlakeComposite sheet is separated into pieces by dicing.



- Finalized customer's product

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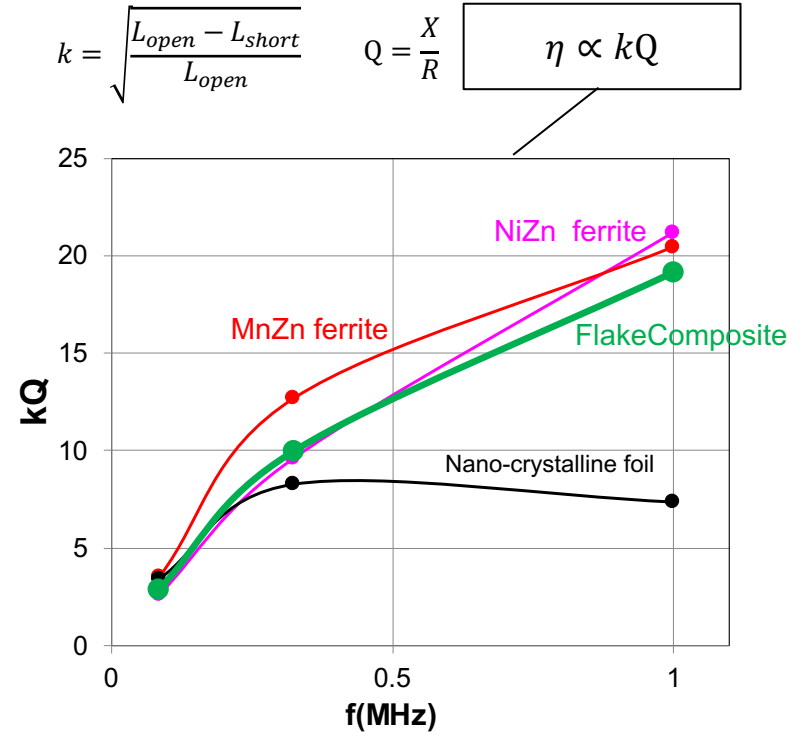
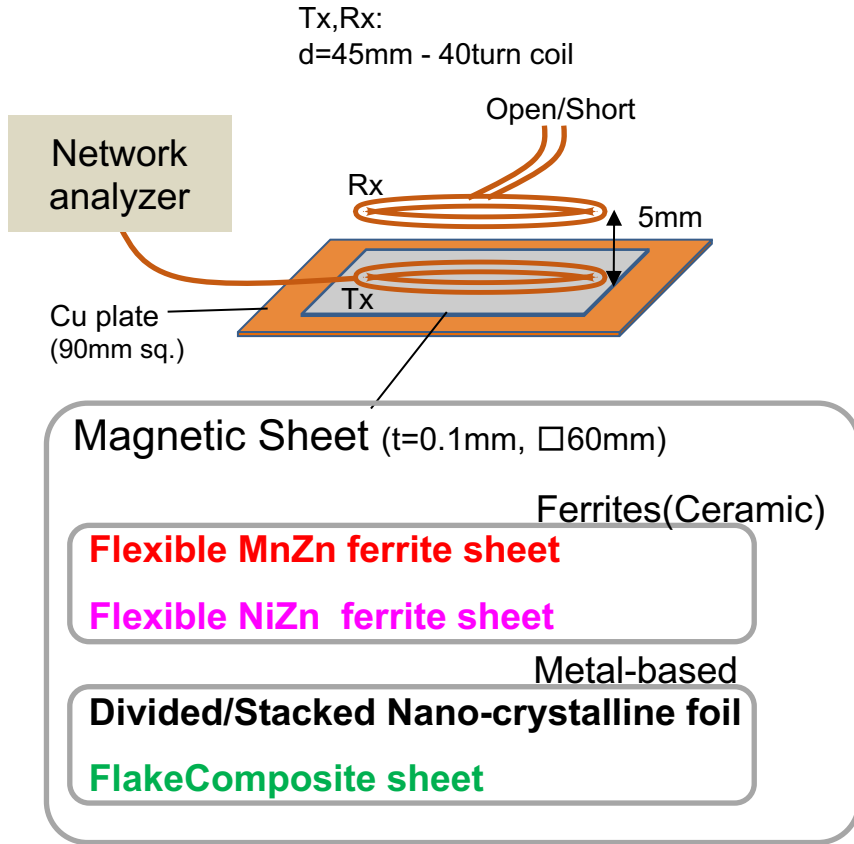
- Internal structure
- Magnetic performance
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■ Application to High Frequency Inductive Components

- Magnetic sheet for Wireless Power Transfer
- PCB Embedded Noise Suppression Concept

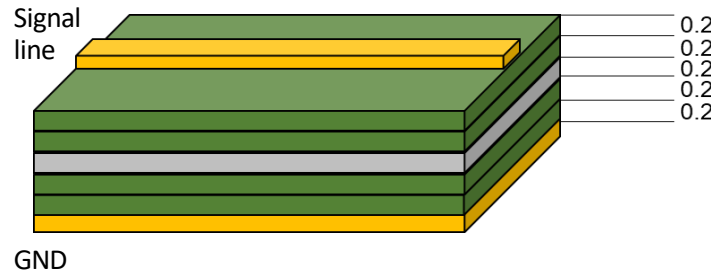
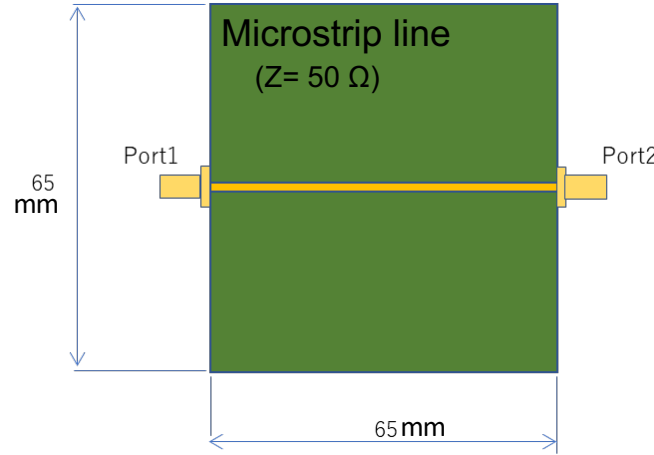
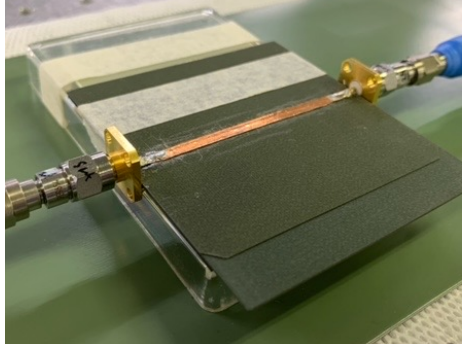
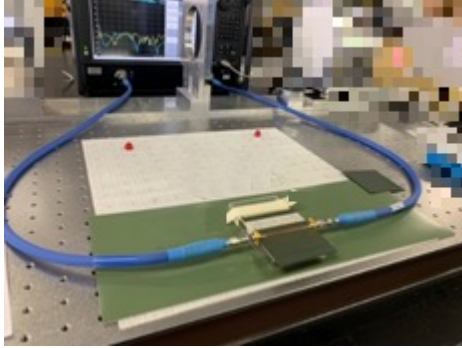
■ Summary

Comparison of Magnetic Sheet for WPT Coil



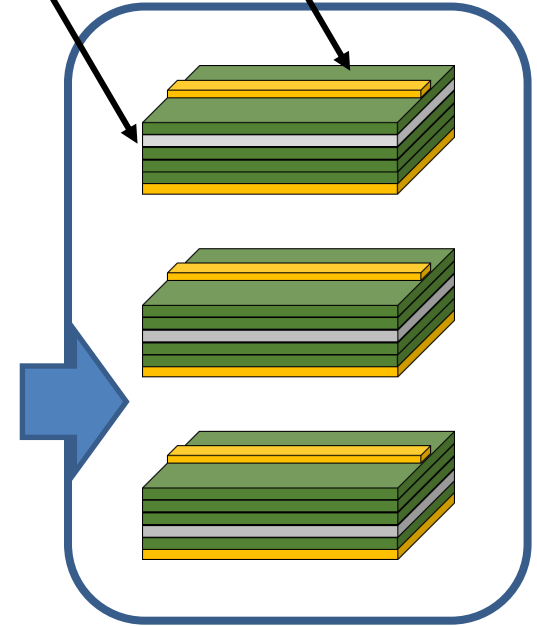
- FlakeComposite can work similarly as ceramic magnetic sheet up to 1MHz.
- With FlakeComposite, PCB embedded WPT coil can be fabricated. (R&D phase)

PCB embedded Noise Suppression: Test Bench



BT resin
(Mitsubishi Gas Chemical)

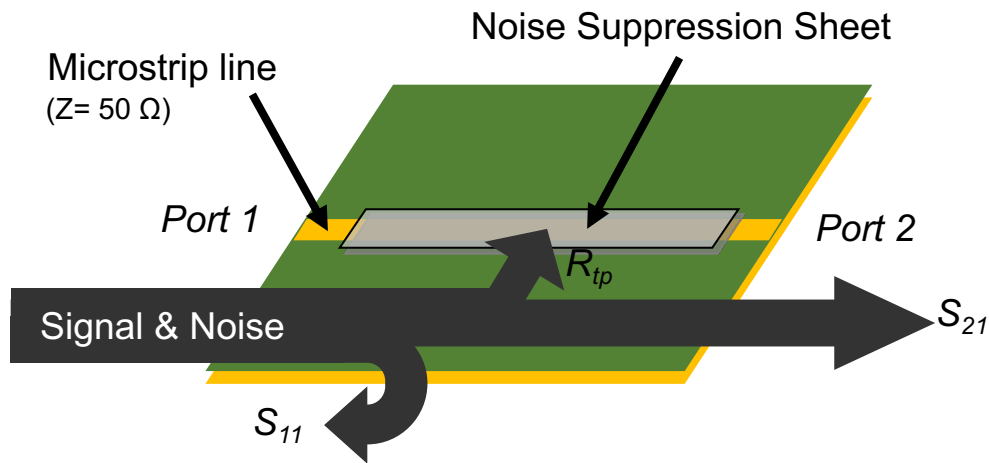
Magnetic Sheet (t=0.2)



PCB embedded Noise Suppression: Referenced Method

IEC 62333-2 Noise suppression sheet for digital devices and equipment - Part 2: Measuring methods.

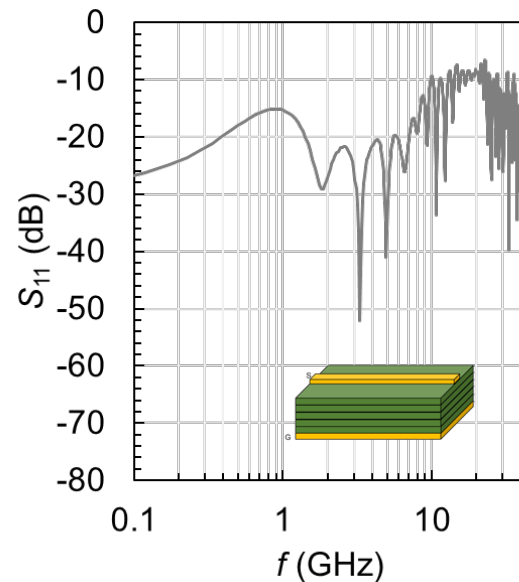
Transmission attenuation power ratio R_{tp}



$$R_{tp} = -10\log_{10} \left(\frac{10^{S_{21M}/10}}{1 - 10^{S_{11M}/10}} \right)$$

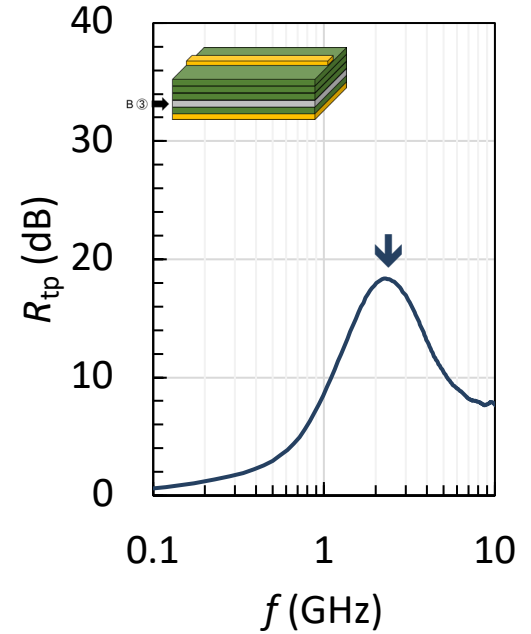
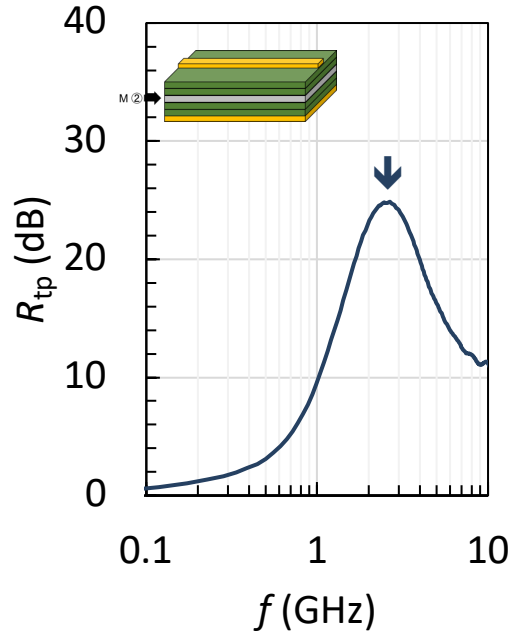
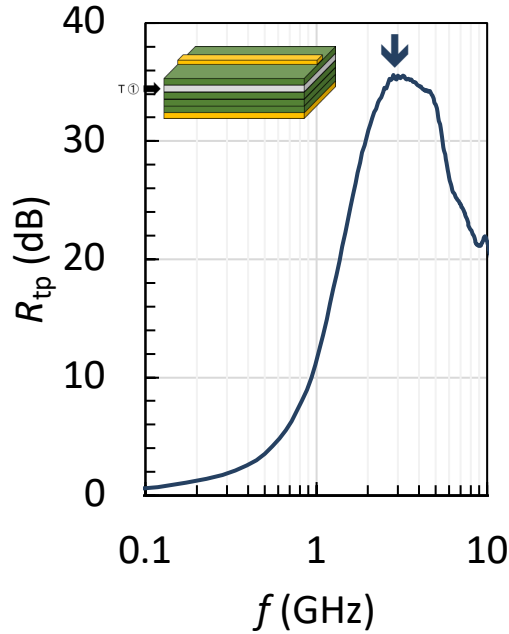
Measured S_{11} without magnetic sheet

Low S_{11} (reflection) was confirmed before measurement.



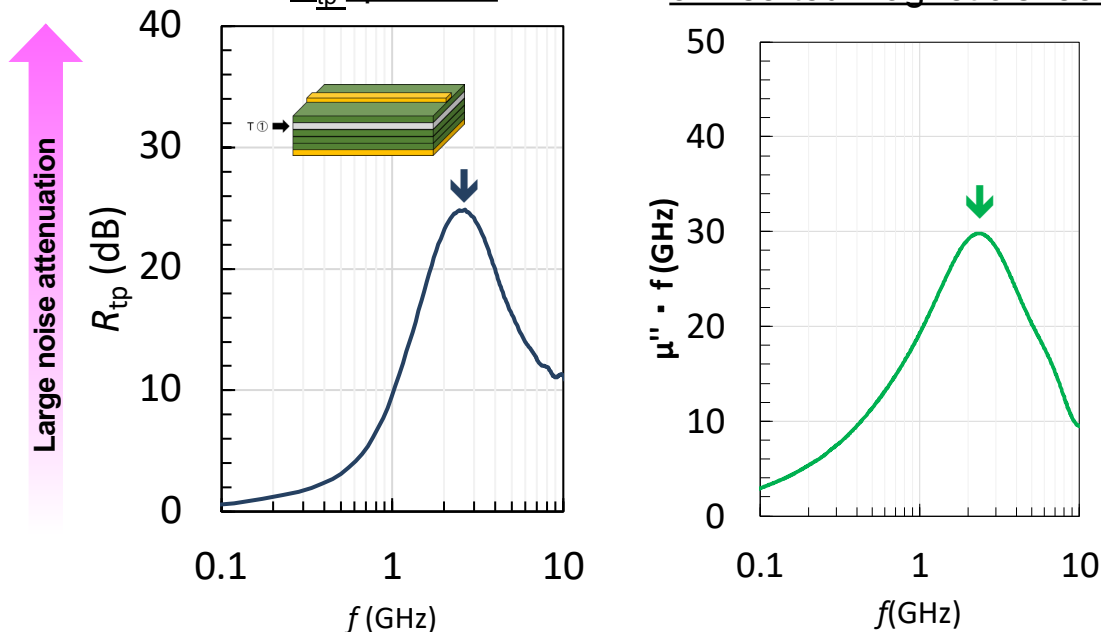
Effect of Insertion position of FlakeComposite

Large noise attenuation

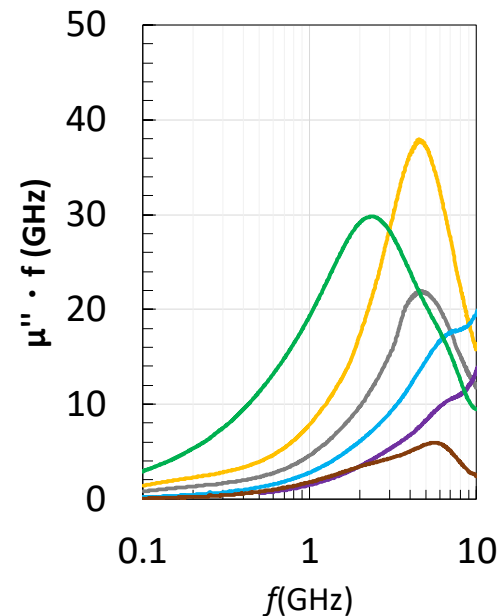


- Large attenuation is observed around 2~3GHz by the insertion of FlakeComposite.
- Larger attenuation is obtained when the insertion position is closer to the signal line.
- FlakeComposite inside PCB can work as GHz noise filter.

Relation between Attenuation and Permeability



- The origin of R_{tp} spectrum is the imaginary part of permeability of inserted magnetic sheet.



- Various GHz noise filtering spectrum can be obtained utilizing the variation of PCB embedded FlakeComposite.

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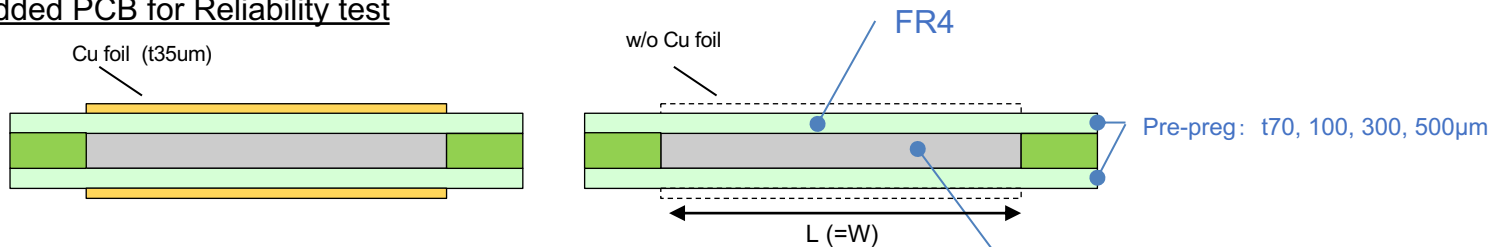
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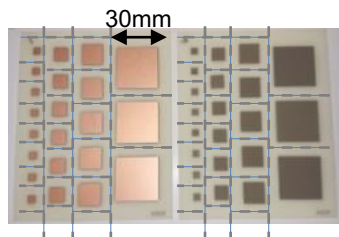
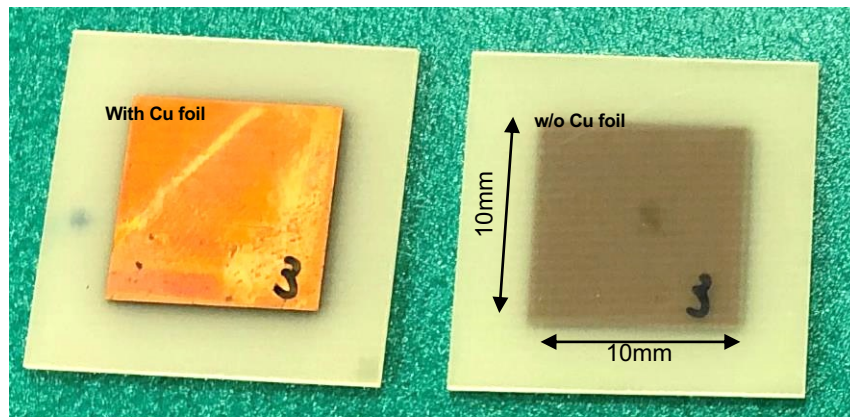
■ Summary

Effort for PCB Embedding Realization

Embedded PCB for Reliability test



PCB
image



→   Totally 1408pcs

- Totally 1408 pcs. of embedded PCB for reliability test was fabricated without failure attributed to PCB embedding of FlakeComposite (failure rate 0%).
- After the qualification to standard reliability tests, sample delivery is planned in 2023.

Summary

- Epoxy binder FlakeComposite is developed to improve its mechanical strength and achieve better compatibility to PCB embedding.
- Permeability in FlakeComposite with epoxy binder is lower than high-temperature annealed FlakeComposite, but it's permeability of 100 is still higher than existing metal composite material (permeability < 30 over MHz region).
- Application of FlakeComposite to power inductor, WPT coil, PCB embedded noise suppression was studied.
- High-frequency performance and compatibility to PCB embedding of FlakeComposite can be implemented as new type of integrated passive components.

Thank you very much for your attention.

ACKNOWLEDGMENT

This study was supported in part by the Ministry of Internal Affairs and Communications, Japan.