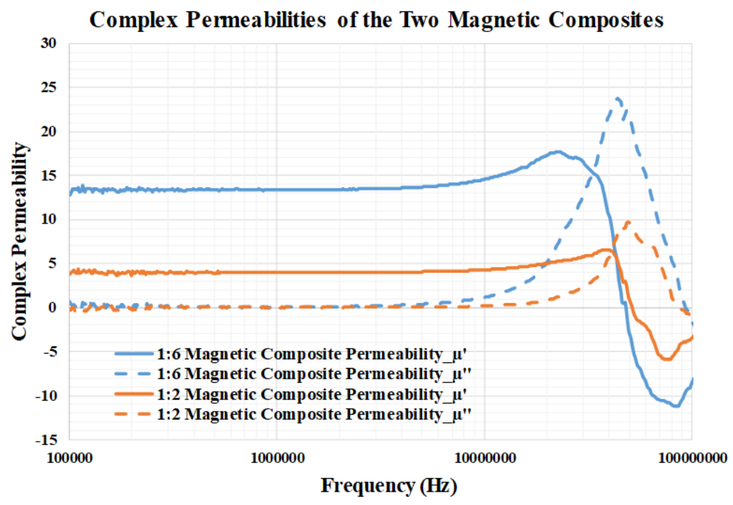
EMI Filter Integration for GaN Power Modules Using Air-Cured Magnetic Composite

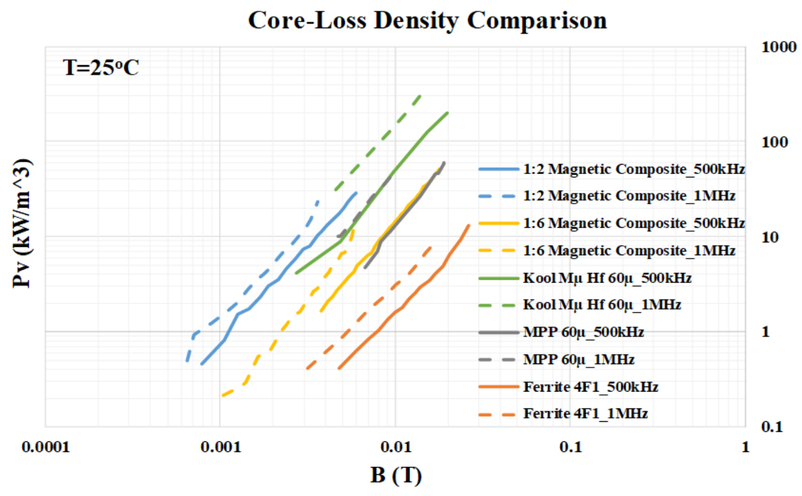
Niu Jia, Leon M. Tolbert, Han (Helen) Cui
The University of Tennessee, Knoxville

Motivation for Over-Molded CMF

- WBG devices produce severe EMI in power electronics systems.
- Package-integrated CM EMI filter is an innovative and effective EMI mitigation method.
- Over-molded CMF (common-mode filter) with magnetic composite is a potential solution for power density improvement of the power module package.

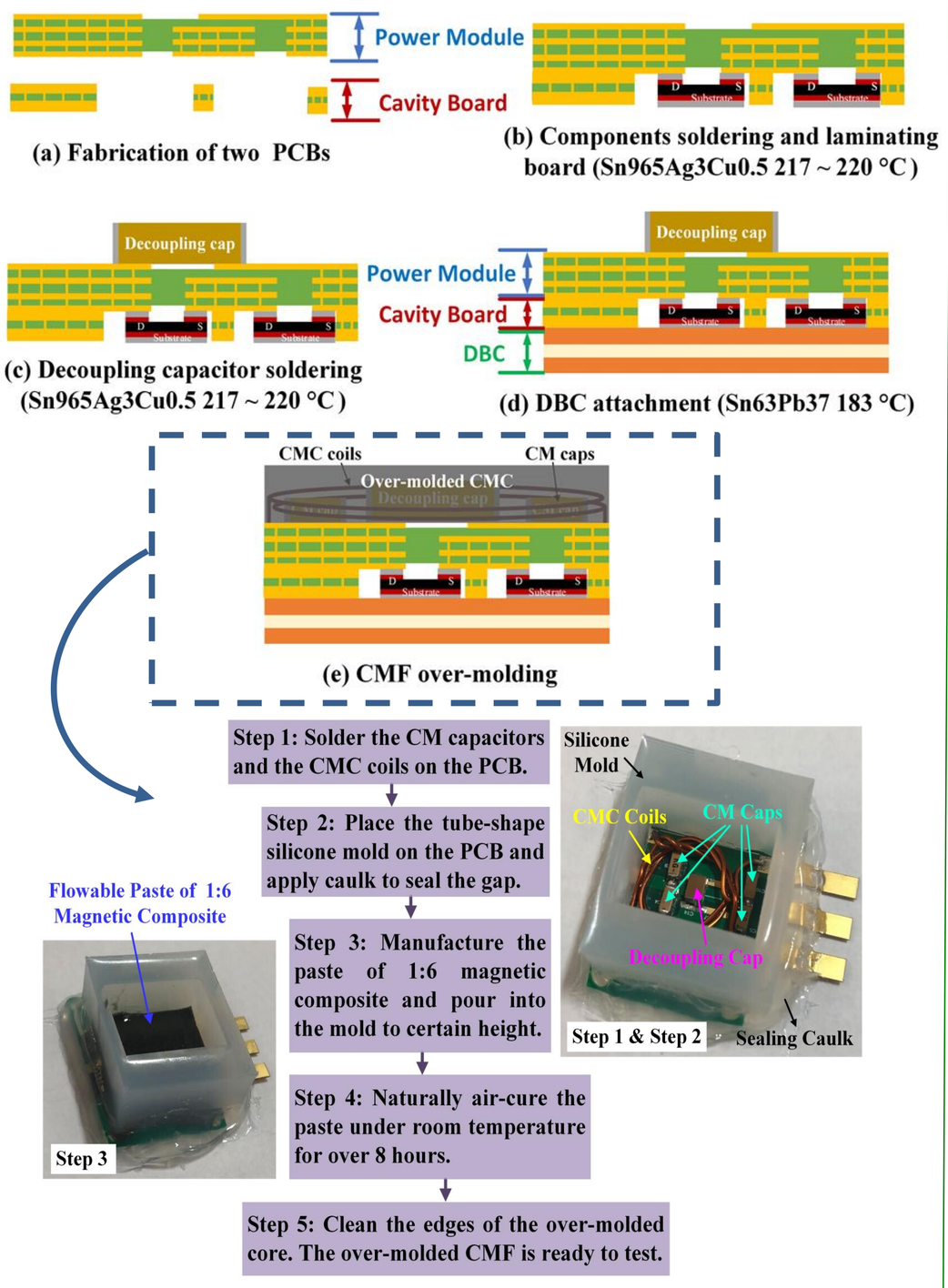
Magnetic Material Characterization





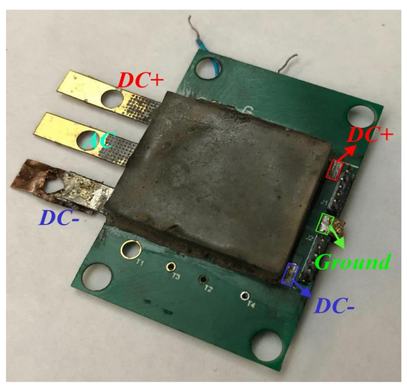
- Magnetic material**: epoxy** & **permalloy powder**
- Material weight ratio: **1:2** and **1:6.**
- Permeability: **13.5** for **1:6 magnetic composite.**
- Core loss: **similar to commercial powder cores.**

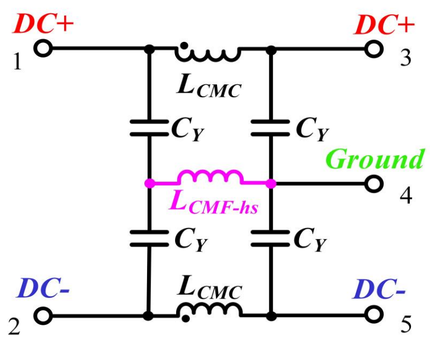
Manufacturing Process



- The over-molded CM choke (CMC) cures **under room temperature**, with **no pressure**, thus **highly package-compatible**.

Prototype and Equivalent Circuit

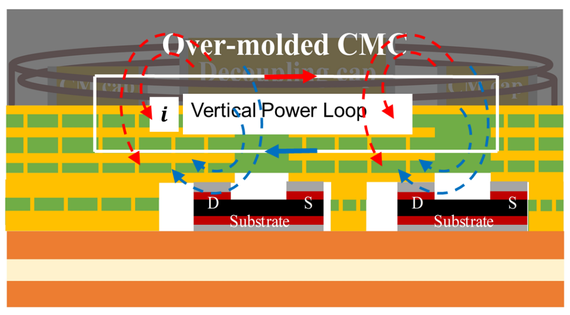


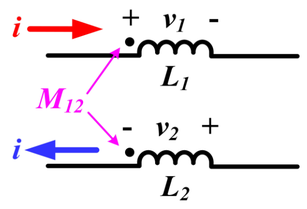


- The impedance of the filter is **measured** by network analyzer and **curve-fitted** to obtain each parameter.
  - L_{CMC} = 240 nH,
  - $L_{CMF\text{-}hs}$ = 30 nH

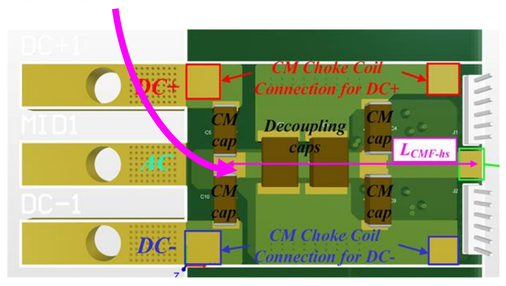
Influence on Parasitics

Lp in lateral PCB trace :
w/o over-molded CMC: 9.6 nH
w/ over-molded CMC: 30 nH



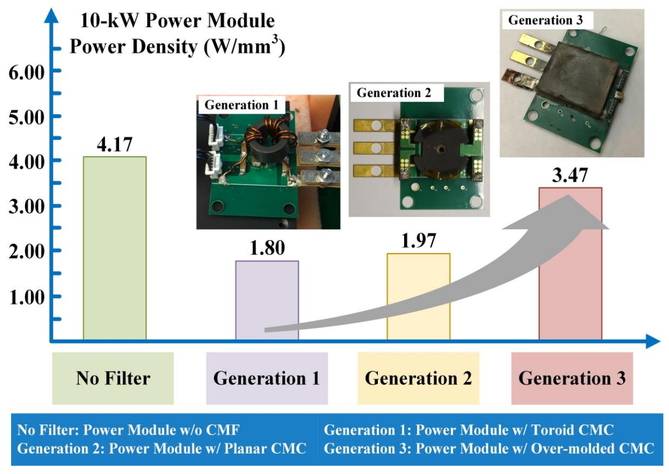


$$L_{loop} = L_1 + L_2 - 2M_{12}$$

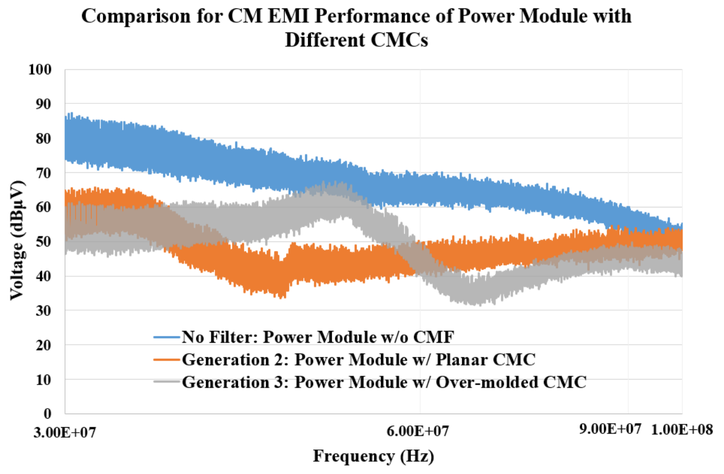


- The power loop parasitic inductance is the same in the vertical power loop w/ and w/o over-molded CMC, verified by double-pulse tests.
- Additional design techniques such as shielding should be applied to lateral loops.

Function Verification and Comparison



- The power density of Generation3 is double of that of Generation1.



- The over-molded CMF realizes an overall attenuation of the frequency range of 30~100 MHz.

Conclusion

- A package-compatible air-cured manufacturing methodology of permalloy-epoxy magnetic composite is introduced.
- Further improving the coil design and the manufacturing process of the magnetic composite would increase the inductance of the over-molded CMC.
- In the future, this manufacturing methodology is possible to be a magnetic integration solution for other WBG power modules or circuits.

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