National University of Ireland, Galway
Ollscoil na hÉireann, Gaillimh

PEI Technologies

PEIG POWER ELECTRONICS INDUSTRY GROUP IRELAND

Loss characterisation of magnetic materials for integration on silicon

M. Duffy, C. Collins,
Power Electronics Research Centre, Department of Electronic Engineering, National University of Ireland, Galway.

Background / introduction :

In the design of magnetic components on silicon, factors relating to core loss contributions include:

- High switching frequencies, in the MHz range
- Eddy current and hysteresis effects
- Sensitivity of materials to processing conditions
- Difficulty in determining core loss contributions in device designs

This work describes methods for measuring the power loss density of electroplated magnetic alloys **prior** to their integration in silicon.

- most suitable materials for a given application may be identified
- impact of processing conditions may be determined
- relative contribution of core loss to total loss can be determined
- developments for improved efficiency may be more easily identified.

Power Loss Characterisation Technique

Loss characteristics are measured using the transformer method with the equipment set-up shown in Fig. 1.

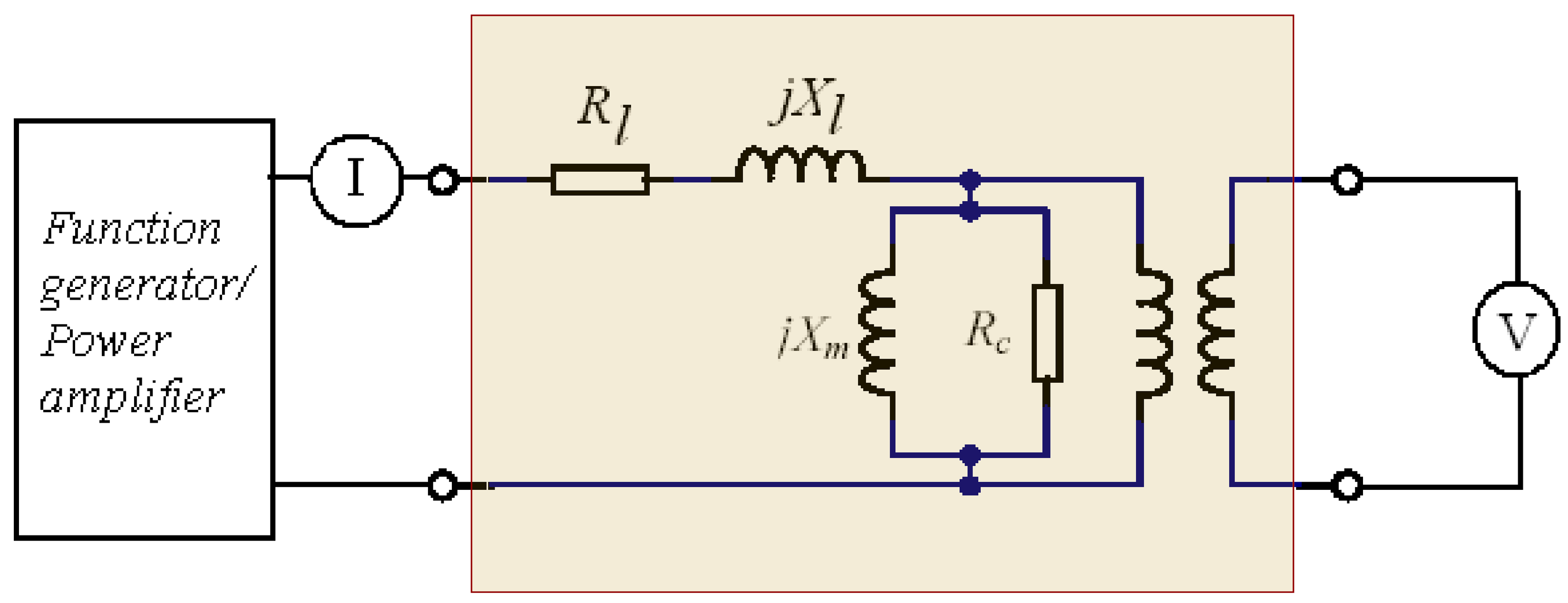

Fig. 1 Loss characterisation equipment set-up

The material sample should form be in the form of a closed core, uniformly wound with two windings having equal numbers of turns. A voltage source is applied to the primary winding and the open-circuit voltage, V, is measured on the secondary side.

Assuming the equivalent circuit model shown in Fig. 1 for the wound sample, total core loss is found as the power dissipated in the resistor R_c:

$$P = \frac{1}{T}\int_0^T v(t)i(t)dt$$

Losses are usually normalised to produce plots of power loss density, P_v, versus magnetic flux density, B, where:

$$P_v = \frac{P}{V_{mat}}, \qquad B = \frac{1}{NA_c}\int_0^{t_{max}} v(t)dt$$

- v_{mat} is the volume of the material sample
- N is the number of turns on the secondary winding
- A_c is the cross sectional area of the material sample
- t_{max} is the time at which B is at its maximum value

Losses due to different operating voltage waveforms can be determined in this way.

Practical measurement issues

- Compensation for air-core flux is applied using measurements on an equivalent air-core structure
- Current probe delay is accounted for using measurements on an air-core sample
- Oscilloscope sampling rate limits the frequency range of measurements

Comparison of different metal alloy losses

Results of power loss density for two different alloys are compared with ferrite and powdered metal materials at 3 MHz in Fig. 2. Sinusoidal excitation waveforms were applied in this case.

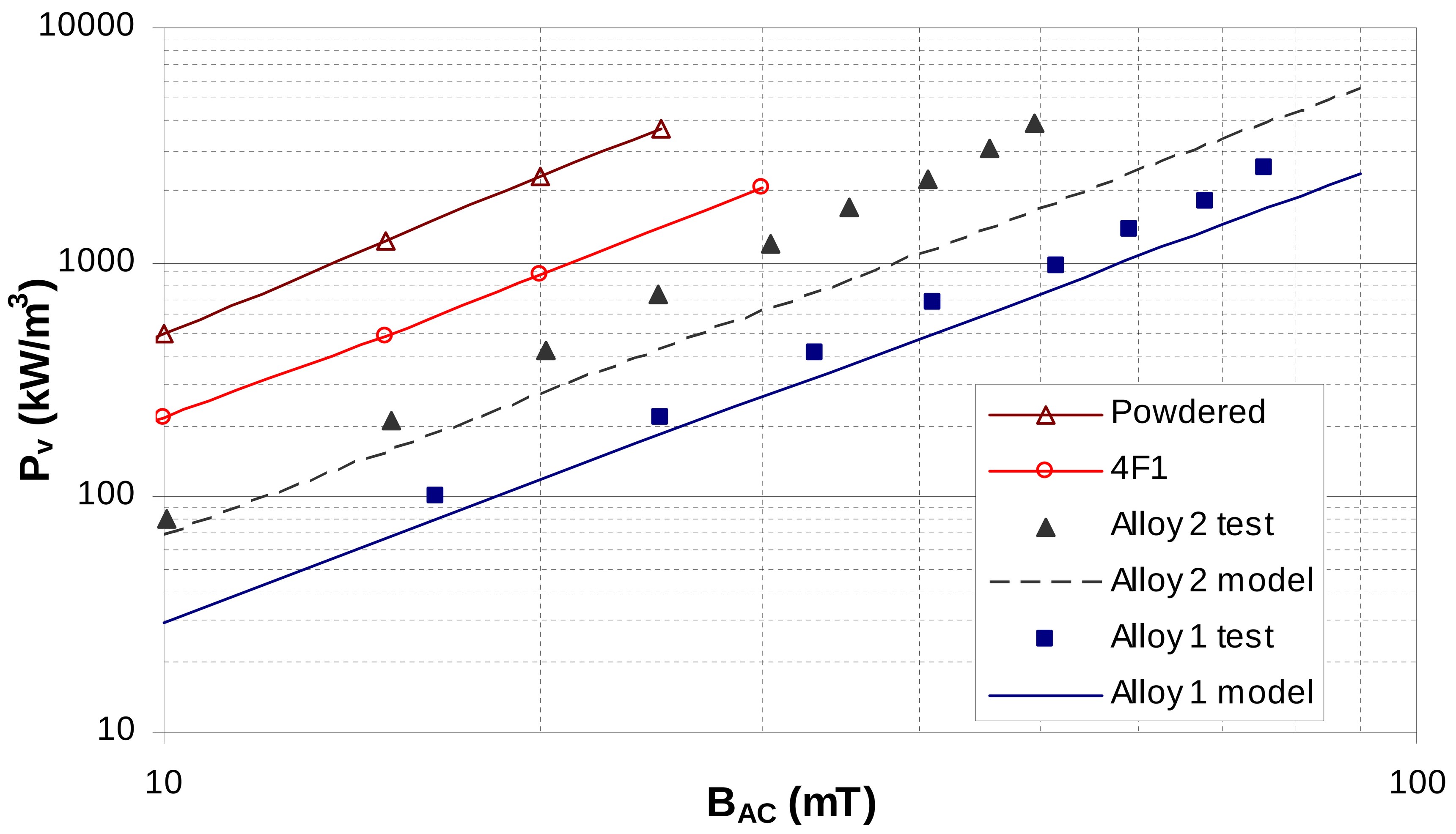

Fig. 2 Comparison of material loss properties

- ➢Measurement procedure was verified through matching results with commercial material's data
- ➢Metal alloys provide superior performance to commercial materials in the MHz range
- ➢Models for eddy-current and hysteresis losses show correct trends in loss characteristics

Work is ongoing to measure losses under non-sinusoidal excitation conditions such as in a VRM as shown in Fig. 3.

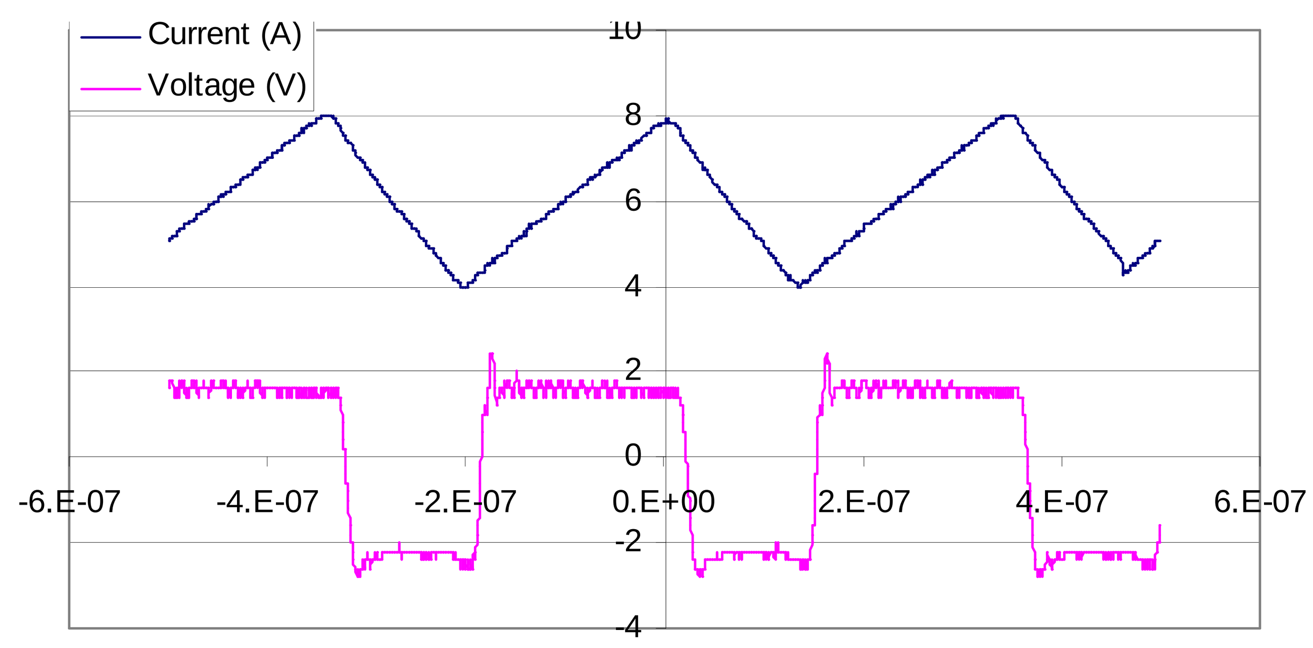

Fig. 3 DC/DC excitation waveforms

Future work will develop loss models to improve the accuracy of loss predictions and to account for non-sinusoidal operating waveforms.

The authors would like to acknowledge the contributions of researchers in Tyndall National Institute who provided material samples, and in UCC who provided the test VRM circuit.
This work was funded by **Enterprise Ireland, The National Development Plan** and the **European Union** under the Industry Led Research Programme in Power Electronics