Abstract

High Frequency Characterization and Modeling of Loss in Magnetic Thin Films

by Denis SHISHKOV

The introduction of magnetic materials within electronic circuits has allowed circuit designers to develop devices that satisfy a variety of consumer needs. Chokes, Reactors and Transformers have all become essential to the operation of circuits such as DC and AC power converters, which in turn are utilized in modern power electronics such as data center motherboards and commercial power systems. Within these circuits, the characteristics of the magnetic materials within these devices are often the performance bottleneck, limiting the optimal operation of the circuits. Particularly, the magnetic saturation, which translates to a maximum current on the component, and the magnetic core loss, which translates to a major component of the overall loss within the actual device, impose constraints on the current density and the efficiency of power converters.

There are two primary concerns limiting the improvement of the bottleneck imposed by magnetic devices. The first is that there are extreme difficulties in estimating properties of a magnetic core from its chemical composition, necessitating in-depth characterization capabilities to determine the behavior of magnetically cored devices. Even with knowledge of the magnetic properties, a second complication arises in that the non-linearities due to changes in the stimuli frequency and amplitude of the magnetics make the simulation of the performance of magnetic devices an onerous task. These unsolved problems are exacerbated by the adoption of thin-film magnetics in silicon integrated circuits, which are more difficult to both characterize and simulate.

This thesis investigates various magnetic core measurement methods with the express purpose of identifying the most suitable method for the characterization of thin film magnetics. The mechanisms and implementation of the chosen method, a modification of capacitive cancellation, is thoroughly discussed. Moreover, a novel approach enabling the direct comparison of magnetic films and expeditious measurements is introduced and discussed. Finally, a comprehensive model of measured magnetic films is presented. This model utilizes the Jiles-Atherton magnetic model in conjunction with an electrical representation of magnetic force and flux to allow for circuit level simulation of magnetic devices in a transient simulation. The results of this work will allow designers to have greater insight in terms of how the magnetic devices will impact their circuits and how to improve the performance thereof by constructing films with different chemical compositions.