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M.E. Rizou, T. Prodromakis

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Electrothermal deterioration factors in gold planar inductors designed for microscale bio-applications

M. E. Rizou and T. Prodromakis

Electronic Materials & Devices Research Group, Zepler Institute, University of Southampton, University Road, SO17 1BJ, Southampton, UK

e-mail: m.rizou@soton.ac.uk, t.prodromakis@soton.ac.uk

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Abstract

In this study, we present the fabrication of wafer level micro-inductors, designed for non invasive neuro-stimulation in vitro, along with an electrothermal study testing the influence of thermal phenomena to their performance. The electric performance of all micro-scale electromagnetic components is hampered by two dominant factors: Joule heating and electromigration. The scope of the study is to evaluate how these phenomena change the electric behaviour of the samples during activation. We experimentally define the safe area of operation across six types of samples with different geometric characteristics and we extract useful information for the reliability of the samples by comparing their median failure times. Our findings present the activation restrictions which should be taken into account in order to avoid the thermal degradation of the components, while at the same time could be used as design guidelines for similar geometries.

1. Introduction

The need of downscaling inductors in integrated circuits has been a long term requirement for a broad range of applications, while the development of microfabrication techniques has assisted towards this direction. In the majority of applications micro-coils are usually exploited in the radiofrequency (RF) range. Typical examples can be found in antenna applications, transformer designs [1,2], low noise amplifiers [3] and filters. In tandem, a number of different technologies [4] and geometries [5] have also been proposed in order to improve their performance and enhance their efficiency. Integrated inductors have also been used as sensors [6], in microscale NMR applications [7] and as transmitter-receiver systems for human body implants [8].

Recently the need of scaling down the size of the electromagnets is coming rapidly into the foreground in the field of bio-medical applications. In vitro, decreasing the size of the inductors is translated into high spatial resolution in either selectivity or sensing applications. At the same time, similar devices transferred to flexible substrates, could be used in vivo, serving the constantly growing need for devices implanted into living tissue. A bio-application which has attracted significant attention over the previous years is magnetic neuro-stimulation, which could be used as an alternative non-invasive method for exciting neural cells both in vitro [9,10] and in vivo [11,12]. The method is based on Faraday's law of induction and the idea was inspired by the clinical method of transcranial magnetic stimulation (TMS) [13,14], where an inductor is used to evoke activity on specific brain regions, used for treatment of