Chapter 11
Fabrication of Excitation Coils for Electromagnetic Microactuators

F. Pape, A. Waldschik, C. Ruffert\textsuperscript{1}, O. Traisigkhachol, M. Feldmann, T. Kohlmeier, V. Seidemann, S. Büttgenbach\textsuperscript{2}, H. H. Gatzen\textsuperscript{1}

\textsuperscript{1}Institute for Microtechnology (now: IMPT) Leibniz Universität Hannover
ruffert@impt.uni-hannover.de; gatzen@impt.uni-hannover.de

\textsuperscript{2}Institute for Microtechnology Technische Universität Braunschweig
s.buettgenbach@tu-braunschweig.de

A key component for electromagnetic micro devices is the coil. Exposing it to an electric current results in exciting a magnetic field. The three coils most commonly used in microactuators are the meander, the planar spiral, and the helical type. For fabricating these coils in thin-film technology a combination of photolithography (for creating a micromold) and electroplating (for creating a Cu coil pattern) is applied. As insulation materials, either a photosensitive epoxy (\textit{SU-8}) or stress compensated Si$_3$N$_4$ lends itself for usage. For helical coils, both horizontal and vertical patterns are required. For such an application, an electrophoretic photoresist is used.

11.1 Introduction

Excitation coils are a basic component of any electromagnetic or electrodynamic microsystem. Their purpose is to convert an electric current into a magnetic field $H$. By doing so, they are creating a magnetic flux $\Phi$. Coils may be applied being surrounded by air or in conjunction with a highly permeable magnetic circuit. Fig. 11.1 depicts the most common types of excitation coils fabricated in thin-film technology. Fig. 11.1.a shows a meander coil. Due to its planar structure, it is the most simple thin-film coil: its whole conductor is created in a single fabrication step. A meander coil induces a magnetic flux $\Phi$ perpendicular to the wafer it is fabricated on. If used in conjunction with a magnetic circuit, its poles are located inside the meanders [7]. Fig. 11.1.b depicts a planar spiral coil. Like the meander coil, it uses planar technology. However, it cannot be fabricated in a single plane, because the inner end of the spiral coil has to be tabbed. Since a second plane is required anyhow, in most cases a second coil layer is used rather than a lead. A planar spiral coil also
induces a magnetic flux perpendicular to the wafer it is fabricated on. If used in a magnetic circuit, there is a magnetic core at its center [10]. Fig. 11.1.c presents a vertical meander coil. It has conductors at the bottom and on top, connected by vias. A vertical meander coil induces a magnetic flux $\Phi$ parallel to the wafer it is fabricated on. Due to its 3D design, a magnetic circuit used in conjunction with it may be chosen as a planar structure [10]. Fig. 11.1.d illustrates a helical coil, which is a 3D spiral coil. Similarly to the vertical meander coil, there are conductors in two planes, also connected by vias. A helical coil induces a magnetic flux $\Phi$ parallel to the wafer it is fabricated on. If used in a magnetic circuit, it has a magnetic core at its center [11, 10].

The coils were fabricated using a combination of photolithography, deposition, and etching techniques. Most commonly, coils were electroplated. In this case, photolithography was used for creating a temporary micromold for the deposition process. Since this deposition process requires a conductive substrate, a seed layer is necessary, which typically was sputter deposited before the micromold was created. After the deposition, the micromold was removed by solvents and the seed layer by dry etching.

The typical coil material is Cu, due to its excellent electric conductivity and its low tendency to electromigration. As favourite material for lateral and vertical insulation as well as general embedding processes, photosensitive epoxy (SU-8) was applied. Rather than being used as a temporary photomask, it serves as a structural material. This is also due to the fact that there is no solvent available for stripping it.

For 3D meander and helical coils, both horizontal and vertical patterning techniques are required. For such an application, an electro-depositable (ED) photoresist may be advantageous since it allows for an even layer deposition.