NiFe 45/55 and its Application in a Strain Gauge Sensor

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Introduction

Exposing a magnetic sample to strain, the material's properties will change, in particular the magnetic permeability decreases. This behavior, which is inverse to the magnetoelastic effect or magnetostriction describing the elongation of a magnetic sample in a magnetizing field, is called the Villari effect. The microtransformer described in this paper benefits from this effect and can be used as an inductive thin film strain gauge. Possible applications are measurements of mechanical forces, pressures, and elongations. A magnetostrictive core made of NiFe 45/55 determines the coupling between the two transformer coils of the microtransformer. The amount of the coupling depends on the magnetic permeability and thus on the strain the core is exposed to [1]. The microtransformer's strain gauge sensitivity factor k is one order of magnitude larger compared to classic metal strain gauges and approximately a thousandfold greater compared to piezoresitive ones [2].

This paper describes investigations regarding the magnetoelastic behavior of NiFe 45/55 thin films used in a microtransformer serving as a strain gauge sensor.

Fabrication process

The microtransformer consists of a pair of planar coils, leads, and contact pads to connect the coils. The magnetic circuit consists of an arrowhead shaped magnetoelastic lower core (sensing bar / NiFe 45/55) and an O shaped upper core (flux closure / NiFe81/19). Figure 1 depicts a top view of the sensor.

The sensor was built up on a silicon wafer by consecutively depositing the lower yoke, coils and three leads, cores, vias, upper yoke, and the second lead of the secondary coil. To create the lower yoke, a 1µm thin film of permalloy (NiFe 45/55) was sputter deposited. To pattern the layer, ion beam etching was applied using AZ5214 resist as a protective layer. A 5µm layer of photosensitive epoxy (SU-8) was used to insulate the lower yoke and the coils. For creating the micromolds for the electroplating process, AZ9260 photoresist is used, followed by executing the respective electroplating process. First, the coils with a height of 5 µm are created. Next, a 5 µm via for connecting the multiturn secondary coil is deposited, as well as the 7 µm thick permalloy (NiFe 81/19) cores. Afterwards, the coils are insulated using SU-8. Finally, the upper yoke made of 3 µm permalloy and the second Cu lead of the secondary coil was deposited by electroplating [3]. Figure 2 depicts a top view of the completed microtransformer. As a last step, the wafer was diced into cantilever beams and each microtransformer contacted using gold wires attached to the contact pads in a bonding process.

Test Results

The properties of the fabricated magnetoelastic films were analyzed as a function of strain. To determine the sensor's sensitivity, measurements using a BH-looper under different compressive stress levels were performed. Figure 3 depicts the normalized initial permeability μ_r as a function of the compressive stress of the magnetoeleastic NiFe 45/55 thin film, resulting in a strain gauge factor *k* of the sensor of greater than 1.500.

Conclusion

The NiFe45/55 material is well suited for the use in a magnetoelastic strain gauge. The excelent magnetoelastic behavior of NiFe45/55 is reflected in a very high strain gauge factor *k* of greater than 1.500 of the completed strain gauge sensor.

Acknowledgement

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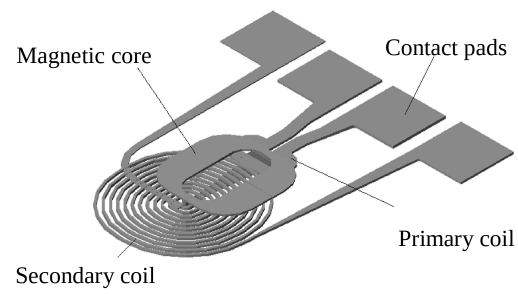

Fig 1: Schematic illustration of the microtransformer

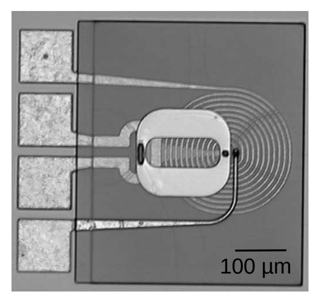

Fig 2: Micrograph of a completed sensor

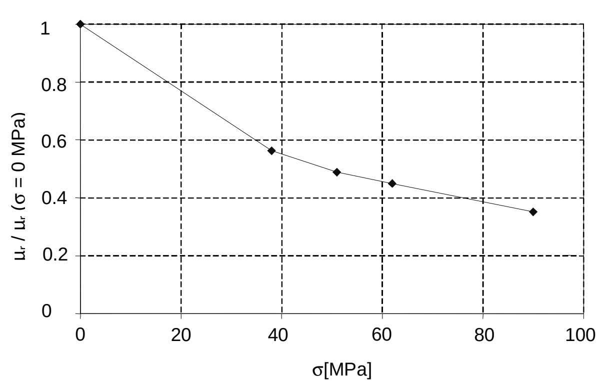

Fig 3: Change of the initial permeability μ_r as a function of the stress applied on the sensing element

References

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