Flexible Fluxgate Sensor

Subjects: Engineering, Industrial

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Fluxgate sensors are magnetic flux density measurement instruments. They are high-accuracy direction sensitive magnetometers that include the Earth's magnetic field in their measuring range. For this reason, they are commonly used for magnetic compass applications. Among others, many current measurement devices are based on fluxgate sensors, since they can measure DC magnetic fields as well as low-frequency AC magnetic fields.

Keywords: fluxgate sensor ; Solenoid coils ; magnetic sensor ; magnetometer ; pad-printing ; flexible electronics ; additive fabrication process

1. Introduction

The fabrication and characterization of a flexible, flat, miniaturized fluxgate sensor with a thin amorphous rectangular magnetic core using the pad/printing technique have been achieved. Both the design and the various printing steps of the sensor are presented. The fluxgate sensor comprises of solenoid coils, and to the best of our knowledge, is the first to be printed with a conventional micro-printing technique. The magnetic core is a non-printed component, placed between the printed layers. The sensor's linear measuring range is ±40 μT with 2% full-scale linearity error, at 100 kHz excitation frequency. The highest measured sensitivity reaches 14,620 V/T at 200 kHz, while the noise of the sensor was found to be 10 nT/ √Hz at 1 Hz. [1][2].

Since a high resolution and precision are less important features in consumer electronic devices, fluxgate sensors have been replaced by anisotropic magnetoresistance (AMR) sensors due to their complicated fabrication techniques [1]. Nevertheless, printed circuit board (PCB) technology [3][4][5][6][7][8], glass microfabrication technology [9][10] and other silicon-based microfabrication technologies [11][12][13] have introduced miniaturized fluxgate sensors, fabricated with simplified techniques.

2. Discussion

Recent developments in various micro-printing techniques allow fluxgate sensors and other microfabricated devices to obtain additional characteristics such as flexibility, ease of integration and eco-friendliness. Micro-printing techniques include inkjet printing, aerosol jet printing, screen printing, gravure printing, flexographic printing and offset printing. A detailed review of these techniques is presented in [14][15][16][17]. Despite their low resolution compared to clean-room techniques, micro-printing techniques can provide relatively fast and simple production methods along with the ease of industrialization. These attractive characteristics can be fully exploited in applications in the domains of the Internet of Things (IoT), wearables and medical devices. Micro-printed devices have already been introduced to the market in the form of Radio-frequency identification (RFID) tags, displays, electrodes, and sensors [17][18][19][20][21]. These devices are known as printed electro-mechanical systems (PEMS) [21].

The fabrication of the sensor presented in this paper is based on the pad-printing technique. The pad-printing technique is an off-set printing technique, which is widely used in the watchmaking industry for the creation of watch-faces. The principles of the fabrication process are explained in [14][21][22][23]. The standard printing cycle is composed of the following steps: the ink cup is filled with ink to produce the motif on the engraved plate. Then, the pad (silicon rubber stamp) transfers the motif of ink onto the substrate.

For the creation of simple sensors, electrodes and conductive tracks, a specific process has been developed which meets the standards of technology readiness level (TRL) 4; thus, the creation of these systems is validated in the laboratory. The biggest advantages of this process compared to other printing techniques are the high printing rate (>1500 prints/h), the ability to use volatile solvents that allow fast drying of the motif onto the substrate, the adaptability of this technique to output range from a small number of fabrication up to mass production, the precise layer-by-layer printing, and the ability to print on non-flat surfaces [14]. All these features made the inclusion of the soft magnetic core in the process possible—an otherwise non-printed component.

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