Sensors and Actuators B 254 (2018) 588–596

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

Asymmetric enhanced surface interdigitated electrode capacitor with two out-of-plane electrodes

Almudena Rivadeneyra[a], José F. Salmerón[a], Manuel Agudo-Acemel[b], Luis Fermín Capitan-Vallvey[b], Juan A. López-Villanueva[c], Alberto J. Palma[c,*]

[a] Institute for Nanoelectronics, Technische Universität München, DE-80333 Munich, Germany
[b] ECsens, Departamento de Química Analítica, Facultad de Ciencias Universidad de Granada, E-18071 Granada, Spain
[c] ECsens, Departamento de Electrónica y Tecnología de Computadores, ETSIIT Universidad de Granada, E-18071, Granada, Spain

ARTICLE INFO

Article history:
Received 4 May 2017
Received in revised form 20 June 2017
Accepted 19 July 2017
Available online 23 July 2017

Keywords:
Capacitive sensor
Flexible substrate
Humidity
Mixed interdigitated-planar plate electrode
Screen printing

ABSTRACT

This work presents a study of high-performance capacitive sensors based on a novel design of interdigitated electrode structure. In the proposed layout, electrodes are placed out of plane and the bottom electrode is a mixed interdigitated-planar plate electrode. Thanks to this layout, the sensor sensitivity is significantly enhanced. This structure has been characterized as humidity sensor manufactured by printing techniques on a flexible substrate. In particular, the sensitive layer is made of cellulose acetate butyrate deposited by screen printing, using silver ink to define the interdigitated electrodes. The capacitance is in the range of hundreds of pF with an area of 95.5 mm^2 at ambient conditions. The response of this sensor shows a sensitivity substantially dependent on the frequency but this sensitivity is considered to be enough to use this device as capacitive sensor in the whole range of frequency studied, for example 5 pF/%RH at 1 MHz. Further characterization was carried out to study the reliability of the manufacturing process and to measure the effect of temperature in the determination of the relative humidity (RH). The capacitive humidity sensor showed a thermal dependence of 0.39%RH/K at 1 MHz.

1. Introduction

Capacitive structures are one of the most common approaches to develop sensors due to their low energy consumption [1,2]. Due to this fact, different strategies have been followed to improve their performances such as modifying their geometry. Specifically, the most common structures are the planar parallel plate [3] and the interdigitated electrode (IDE) [4–6]. The former is characterized by the simplicity of its geometry and the ease of modelling and calculation. The latter structure presents very different and interesting features such as one-side access (the other side can be open to the ambient), control of signal strength by easily changing its dimensions, simpler and more economical fabrication than parallel plate (it only requires one layer), in most cases a 2D modelling is sufficient, and a wide usable frequency spectrum [7]. Moreover, it has been fabricated with different materials and following different manufacturing processes, from integration in semiconductor dices to printing on flexible substrates [8–11].

Several strategies have been followed to improve the sensitivity of interdigitated electrodes [12–14], such as geometrical changes. Kim et al. [15] presented a hybrid IDE-parallel plate capacitor, that is to say, they performed a capacitive structure where the bottom electrode is a planar plate and the top electrode is a single interdigitated electrode with branches. Following a similar philosophy, the structure analysed in this work is a capacitor based on the IDE layout but with a multilayer structure, where the interdigitated electrodes are not in the same plane and the bottom electrode is connected to a planar plate. Therefore, the bulk capacitance is increased as well as the electric field lines between electrodes. Obviously, the complexity of the fabrication process is increased but the enhancement of the sensitivity justifies this drawback. The sensitive element is a polymer deposited on the electrodes and around them. These interdigitated electrodes enhance the capacitance due to their asymmetrical construction and the location out-of-plane of the electrodes in z-axis.

In particular, we have characterized this capacitive sensor as a humidity sensor by the deposition of a sensitive to moisture polymer content around IDE. Concretely, we have chosen cellulose acetate butyrate (CAB), a well-known sensitive material for

* Corresponding author.
E-mail addresses: arivadeneyratorres@nano.ei.tum.de (A. Rivadeneyra), jfsalmeron@nano.ei.tum.de (J.F. Salmerón), manuelagudo@ugr.es (M. Agudo-Acemel), lcapitan@ugr.es (L.F. Capitan-Vallvey), jalopez@ugr.es (J.A. López-Villanueva), ajpalma@ugr.es (A.J. Palma).

http://dx.doi.org/10.1016/j.snb.2017.07.141
0925-4005/

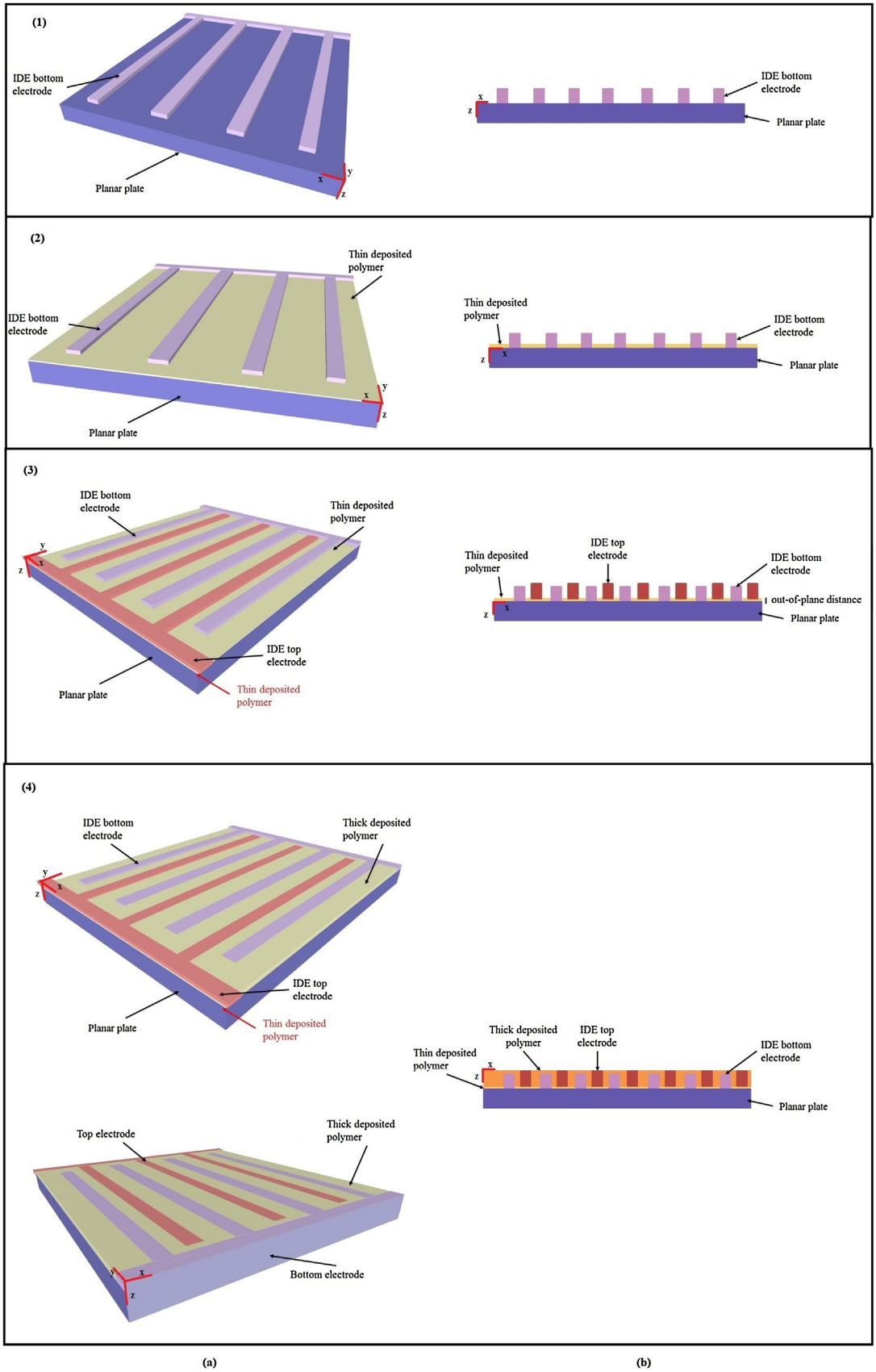

Fig. 1. Capacitive sensor design. (a) 3D view, (b) lateral view.