A NOVEL CHEMICAL SENSOR USING METAMATERIAL ABSORBER FOR METHANOL SENSING APPLICATIONS

Hong Zhou[1,2,3], Donglin Hu[1,2,3], Jia Gong[1,2,3] ,Junwang Ji[1,2,3], Xu Liu[1,2,3], Zhengguo Shang[1,2,3], Yu Chen[4] and Xiaojing Mu[1,2,3,*]

[1] Defense Key Disciplines Lab of Novel Micro-nano Devices and System Technology，Chongqing University, Chongqing, China

[2] International R & D center of Micro-nano Systems and New Materials Technology，Chongqing University, Chongqing, China

[3] Key Laboratory of Optoelectronic Technology & Systems, Ministry of Education, Chongqing University, Chongqing, China

[4]Institute of High Performance Computing, Agency for Science, Technology and Research, Singapore

* Email: mxjacj@cqu.edu.cn; Tel.: +86-15902396712

This paper presents a novel chemical sensor using a metamaterial absorber, which is composed of an Au Bottom layer, a microfluidic channel, a FR4 substrate and a split-square-cross-resonator (SSCR). The resonance generated by SSCR is extraordinarily sensitive to changes of the effective dielectric constant around the capacitive gap. Furthermore, the effective dielectric constant of the dielectric substrate is under the influence of microfluidic channels by using an infinitesimal quantity of a liquid. The proposed sensor exhibits an outstanding sensitivity by a creative SSCR structure and the Au Bottom layer. In addition, the relationship between the absorption frequency and chemical concentration is demonstrated by simulation.

In recent years, unidentified or unlabeled chemicals often occur in experiments. Some of these chemicals are harmful to the human body and health. For example, methanol is fatal to the central nervous system and can cause blindness, coma, or death if it is swallowed [1]. Therefore, the accurate detection and quantification of liquid chemicals used in various applications are essential.
Metamaterial absorbers can be realized using the periodic structures of electric LC (ELC) resonators such as split-ring resonators (SRRs) [2]. The resonance frequencies of metamaterial resonator structures are very sensitive to variations in capacitive and inductive effects because their fundamental resonance response can be modeled by an LC resonant circuit. This characteristic makes metamaterial absorbers suitable for metamaterial sensor applications [3-4].

In order to obtain an excellent metamaterial absorber for chemical sensor application, the SSCR structure is adopted, as shown in Fig. 1(a). Fig. 1(b) shows the exploded figure of the proposed chemical sensor which is composed of an Au Bottom layer, a microfluidic channel, a FR4 substrate and a SSCR. Fig. 2 displays the geometry size (Fig. 2a) and the electric field distribution, which reveals that the incident wave is strongly coupled around the SRCR, especially at the capacitive gaps. Therefore, the microfluidic channel should be designed considering all capacitive gaps of the SRCR.
Fig. 3 shows the electric field distributions of the proposed absorber for different microfluidic channel states. As a result, the proposed chemical sensor has its electric resonance at different frequencies in accordance with the types and concentrations of the substances that fill the microfluidic channels.
As shown in Fig. 4, the resonant frequency is increased from 12.75 to 13.70 GHz when the concentration of methanol is changed from 0% (DI water 100%) to 100%. Thus, the proposed chemical sensor can detect the concentration as well as the dielectric properties of the liquids and exhibits a outstanding sensitivity by a creative SSCR structure and the Au Bottom layer. When the proposed metamaterial resonator is extended to a large periodic array, the chemical sensor can be effectively used for wireless chemical sensors.

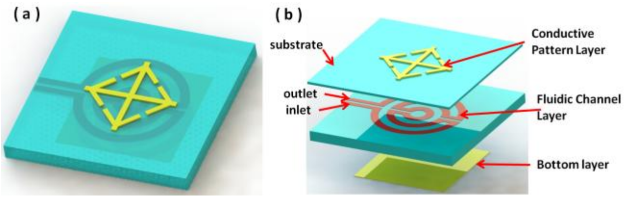

Figure 1: (a) three-dimensional view and (b) exploded figure of the proposed chemical sensor.

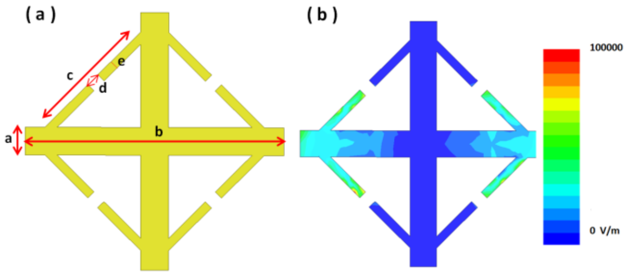

Figure 2 (a) Layout of the proposed metamaterial absorber without microfluidics (a =1, b = 14, c = 9, d = 0.5, and e = 0.4; unit: mm); (b) magnitude of electric field distribution of proposed metamaterial absorber without microfluidics.

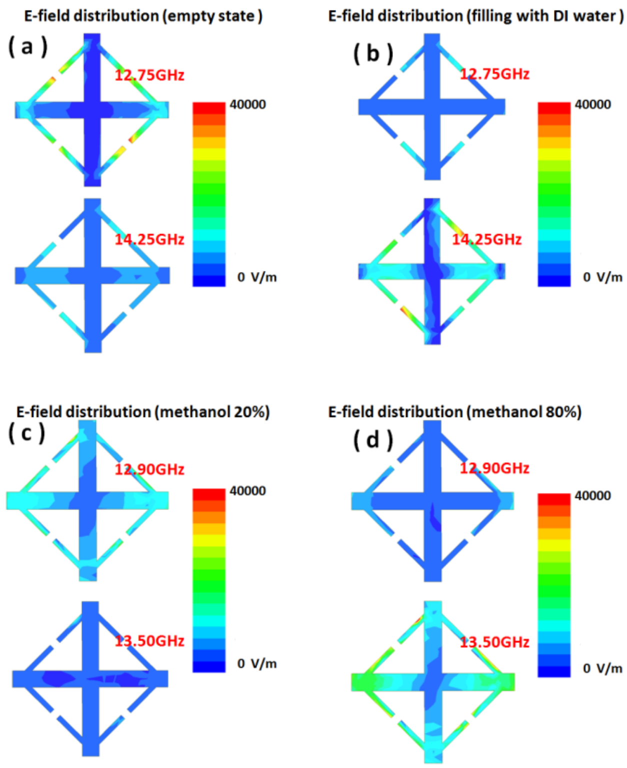

Figure 3: Electric field (E-field) distribution for (a) empty state, (b) filling with deionized (DI) water, (c) 20% concentration of methanol and (d) 80% concentration of methanol.

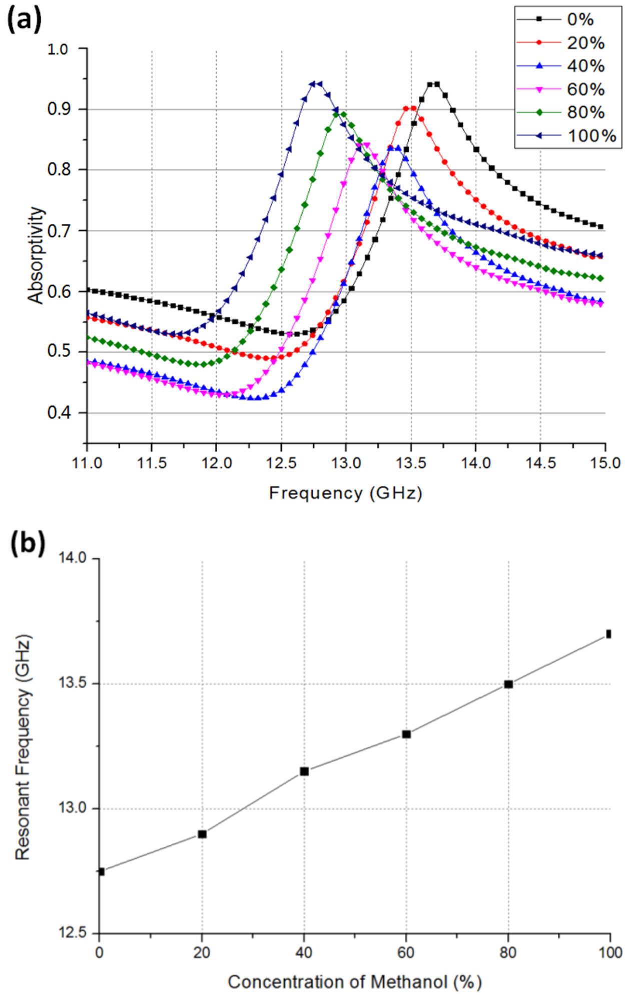

Figure 4: (a) Simulation absorptivity and (b) resonant frequency for methanol with different concentrations, from 0% (DI water 100%) to 100%

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