Supporting Information

Experimental study of dielectric property changes in DMSO-primary alcohol mixtures under low-intensity microwave

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Experimental

We demonstrated a sensitive microwave sensor to investigate the effects of an externally applied microwave fields on the dielectric property of the polar solution. The sensor consists of a forward coupler, a backward coupler, and a bisection Wilkinson power combiner, which were built with planar microstrip lines. Furthermore, two same microstrip rings with uniform electric field distribution were introduced to this sensor.

The principle of the sensor

Fig. S 1 is the schematic and photograph of the proposed high-sensitivity microstrip sensor, which consists of a conventional 20dB backward coupler, a specially designed 20dB forward coupler and a 3dB Wilkinson power combiner. An incoming signal from Port 1 is divided into two uneven parts when it meets the forward coupler. One 20dB signal is achieved by the forward coupler's coupling hand, then it propagates forward, walks across the reference material (REF) channel, and finally arrives at the right-hand side of power combiner. The other signal keeps propagating forward, and sequentially transmits across the material under the test (MUT) channel, 20dB backward coupler, and finally reaches Port 5. Meanwhile, a 20dB signal is also obtained by the coupling hand of the backward coupler, and then it enters the power combiner's left-hand. Furthermore, by altering the distance l_s between the two couplers， we obtain the required 180 degree phase difference of the two 20dB signals. Finally, two identical signals coming from the two couplers reach the Wilkinson power combiner simultaneously, and cancel each other at Port 3 provided that the components in MUT and REF channels are the same. Supposing that the solutions' dielectric properties in the two channels are unchanged, two signals coming from the forward coupler and backward coupler will cancel each other, *i.e.*, $S_{31}=0$. Otherwise, their difference will appear at port 3, and $S_{31}\neq0$, if the dielectric properties of solution in MUT channel change.

Design details

In order to investigate the effects of externally applied electric field on the dielectric response of polar solution while eliminating the thermal effects caused by microwave heating, a pump was employed to drive the solution flowing through the sensor. Furthermore, to realize minimal reflection from the incident port and maximum uniform electric field around the MUT solution, a specially designed via hole in the microstrip ring was introduced in Fig. S 2(A). The ring included a circular hole with inner diameter of 5 mm, a copper ring with outer diameter of 7 mm, and two same sized rectangular coppers (1 mm×0.4 mm) which were etched away. In the sensor simulation, the electric field distribution demonstrated a satisfactory consistency and the averaged field intensity reached 1.17×10^5 V/m at the input power of 66 W as shown in Fig. S 2(B).

Sensor fabrication

Based on the well-designed sensor above, a prototype was fabricated on an F4BME255 substrate (relative dielectric constant ε_r = 2.55, substrate thickness h=1mm, metal thickness t= 0.018mm) at the operating frequency of 2.45 GHz. The characteristic impedances of all ports were chosen as Z_0=50 Ω and the isolation resistance was R=100 Ω. Full-wave simulations for the sensor were performed in bandwidths from 2.0 GHz to 3.0 GHz.

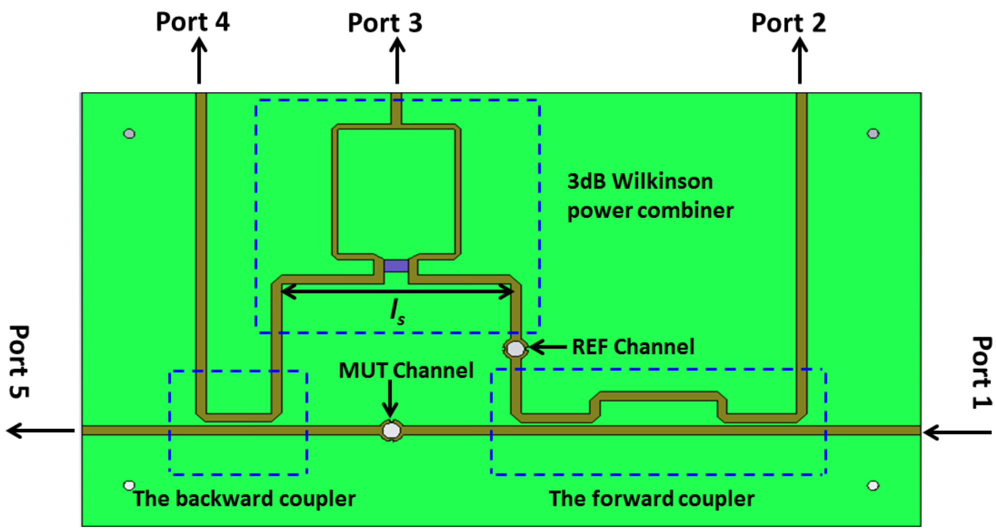
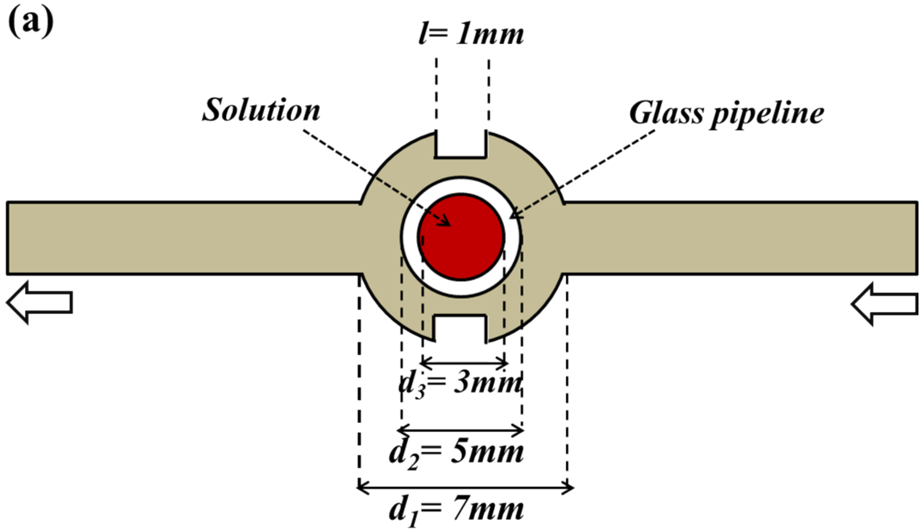


Fig. S1: The schematic of the proposed high sensitivity sensor.

(a)



(b)

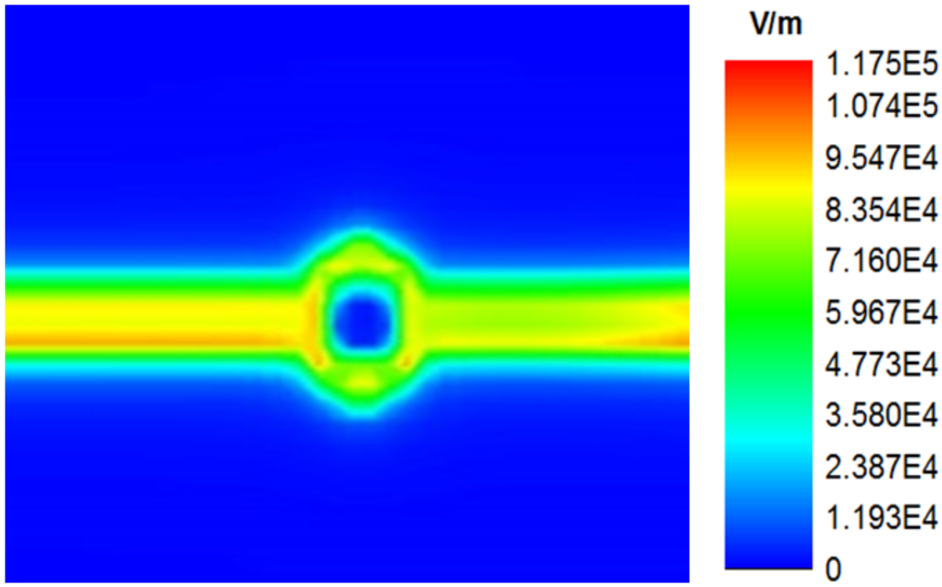


Fig. S2 (A) The schematic diagram of the via hole microstrip ring circuit; (B) The averaged electric field distribution for the design ring at the input power of 66W.