*Proceedings of International Conference on Technology and Social Science 2018 (ICTSS 2018)*
**Invited Paper**

# Disturbance on Device Under Test by Dielectric Material Used in Electro-Optic Sensor

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**Keywords:** dielectric material, disturbance, electro-optic crystal, relative permittivity, S-parameter

**Abstract.** We reported a measurement error analysis of an electro-optic (EO) crystal in previous work. In general, an EO crystal is incorporated into a sensor system by using a dielectric material: cover and holder. This paper describes a disturbance on a device under test by the dielectric material by using an electro-magnetic field simulator. The disturbance by the dielectric material is large when the dielectric material is close to the device under test. We also found that the dielectric material changed electrical impedance characteristics of the device under test.

## 1. Introduction

An electro-optic (EO) probe system is a low disturbance probing technique. For example, the EO probe system is used for a measurement of an integrated circuit and an organic photovoltaic [1]-[4]. We reported a measurement error analysis of an EO crystal [5]. The measurement error becomes large when the EO crystal is close to a device under test (DUT). In general, the EO crystal is incorporated into a sensor system by using dielectric material: cover and holder. We try to examine the disturbance by the dielectric material by an electro-magnetic field simulator.

## 2. Disturbance by Dielectric Material

Fig. 1 shows a schematic of the disturbance by the dielectric material. The disturbance is negligible small when the dielectric material is far from the DUT as shown in Fig.1 (a). The disturbance is large when the dielectric material is close to the DUT as shown in Fig.1 (b). We think that there are two types of disturbance. One is a disturbance on an electric field from the DUT. The other is a disturbance on an impedance of the DUT. These disturbances might cause the measurement error. We try to examine these disturbances by the dielectric material by the electro-magnetic field simulator.

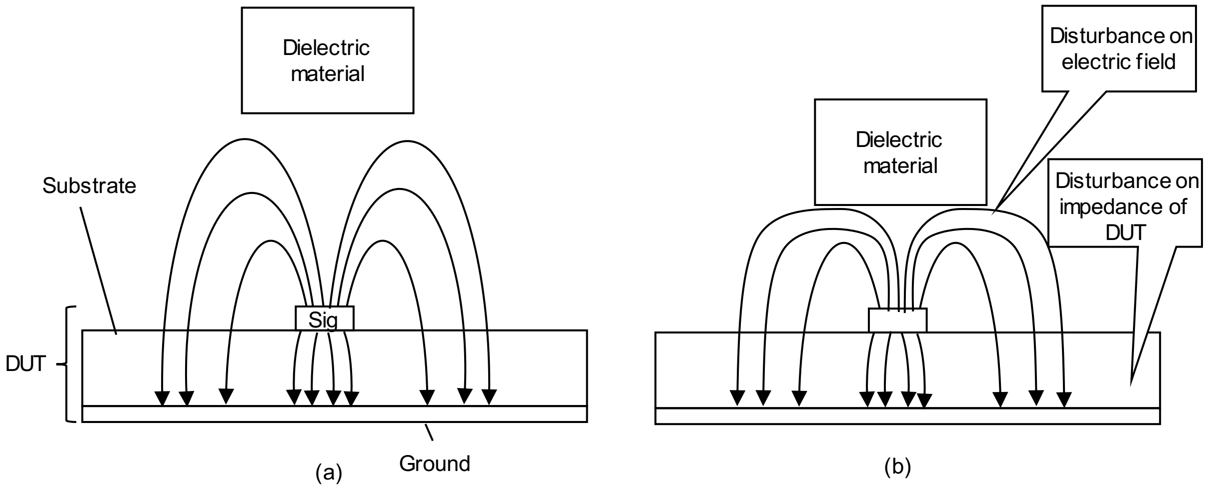



Fig. 1. Schematic of disturbance by dielectric material.

## 3. Simulation Model

Fig. 2(a) shows a simulation model using a micro strip line and the EO crystal with a dielectric cover. The substrate of the micro strip line is made of glass epoxy. The signal electrode and the ground electrode of the micro strip line are made of Copper. A sinusoidal signal is applied between the signal and ground electrode of the micro strip line. The frequency of the signal is 100 MHz and the amplitude of the signal is 1 $V_{P\text{-}P}$. Fig. 2(b) shows a cross section of the simulation model. ZnTe is used as an EO crystal. The size of the EO crystal is 3 mm × 10 mm × 1 mm. The EO crystal is assembled with a 1-mm thickness dielectric cover. A probe point is at center of the EO crystal. The electric field strength in Z-direction is obtained at the probe point. *D* is a distance from the top surface of the signal electrode to the probe point. The electric properties of the micro strip line and the EO crystal are summarized in Table 1.

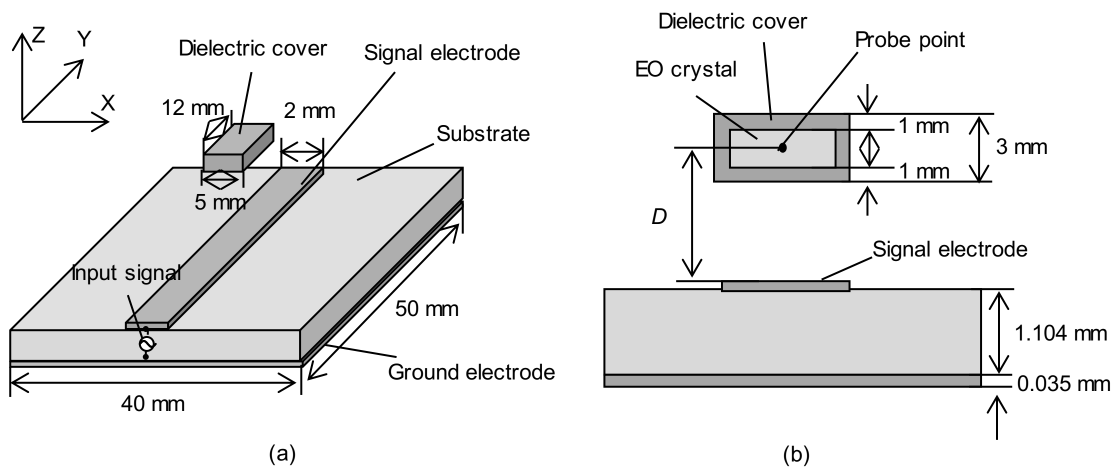



Fig. 2. (a) Overall view of simulation model and (b) cross section of simulation model.

Table 1 Model name and electric property

| Model name | Material | Relative permittivity | conductivity [S/m] |
|---|---|---|---|
| Substrate | glass epoxy | 4.6 | |
| Signal electrode | Copper | 1 | $5.8\times 10^{7}$ |
| Ground Electrode | Copper | 1 | $5.8\times 10^{7}$ |
| EO crystal | ZnTe | 10 | |

## 4. Simulation result

### 4.1. Electric Field Strength

We used the electro-magnetic field simulator based on finite-element method. The relative permittivity of the dielectric cover is varied at 1, 2.2, and 20. The distance *D* is changed from 2 mm to 11 mm. Fig. 3 shows the *D* dependence of the electric field strength. Circle mark (○), rectangle mark (□), and triangle mark (△) show the results at the relative permittivity of 1, 2.2, and 20 respectively. The electric field strength strongly depends on *D* in region of less than 5 mm. We think that the dielectric material including the EO crystal and the dielectric cover attract the fringe electric field which escape to the ground electrode. Fig. 4 (a) shows the attraction to the electric field by the EO crystal. A broken circle area of Fig. 4 (b) shows the attraction by the dielectric cover having the relative permittivity of 20. The attracting factor depends on the relative permittivity of the dielectric cover. Therefore, the electric field strength at the probe point becomes large when the relative permittivity is large. On the contrary, *D* dependence of the electric field strength is small in *D* region of more than 5 mm, because the electric field strength of Z-direction is dominant.

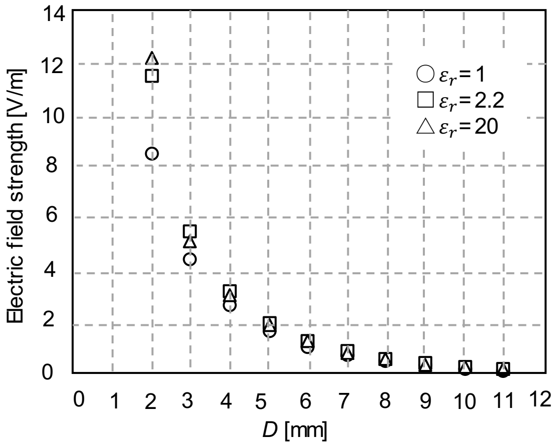



Fig. 3. *D* dependence of electric field strength.

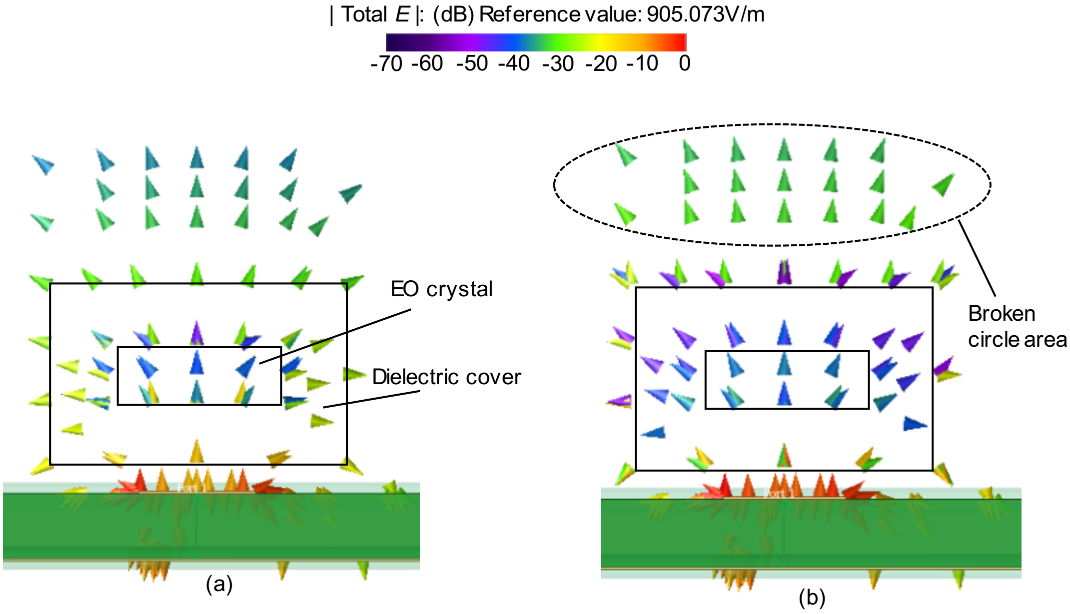



Fig. 4. Attraction fringe electric field by (a) EO crystal and (b) dielectric cover

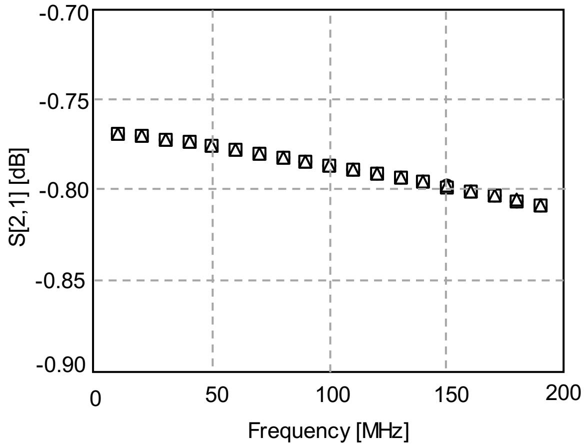
A disturbance factor, *N*, accordance with relative permittivity of the dielectric cover is defined as

$$N = \frac{E_r(D)}{E_1(D)} \quad (1)$$

Here, $E_r(D)$is the electric field strength with the relative permittivity *r* and distance *D*, and $E_1(D)$ is that with the relative permittivity of 1 and *D*. The *N* of $E_{20}$(2 mm) is larger than that of $E_{2.2}$(2 mm) from Fig. 3. It means that the large relative permittivity causes large disturbance.

### 4.2. S-Parameter

We simulate S-parameter of *S*[2,1] and *S*[1,1] for examining the disturbance on the impedance of the micro strip line. Fig. 5 shows the frequency dependence of *S*[2,1] and *S*[1,1]. *S*[2,1] is independent of the relative permittivity as shown in Fig. 5 (a). On the contrary, *S*[1,1] depends on the relative permittivity especially in frequency region of more than 100 MHz as shown in Fig.5 (b). The characteristics of $S$[1,1] at 100 MHz agree with the results as shown in Fig. 3. This means that the impedance disturbance of the micro strip line depends on the relative permittivity of the dielectric cover.



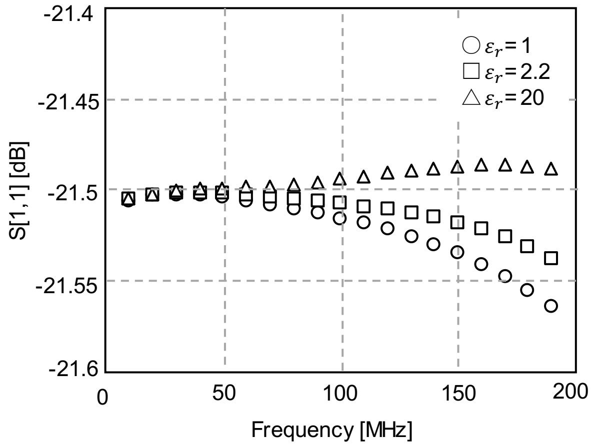




Fig. 5. Frequency dependence of (a) $S$[2,1] and (b) $S$[1,1].

## 5. Conclusion

We examined a disturbance on a device under test by a dielectric material used in an electro-optic sensor by an electro-magnetic field simulator. The dielectric material attracts a fringe electric field which escape to a ground electrode of a device under test. We also found that an impedance disturbance of the device under test depends on the relative permittivity of the dielectric material.

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