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Topic E2: Transportation & Mobility

The Euromat conference series, organised by the Federation of European Materials Societies (FEMS), is one of the largest events of its kind in Europe, covering the full width of materials science and technology. We would like to direct your attention to the following Symposia which are focussing specifically on transport applications:

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Prof. Kambiz Kayvantash, Société CADLM, Massy (F)

E2.II: **Intelligent and adaptive materials and structures**
Dr.-Ing. Dirk Lehmhus, ISIS Sensorial Materials Scientific Centre, Bremen (D)

E2.III: **Energy absorbing and protective materials and structures**
Prof. Massimiliano Avalle, Politecnico di Torino, Torino (I)

E2.IV: **Production, properties and applications of hybrid materials and structures**
Dr.-Ing. Kai Schimanski, Foundation Institut für Werkstofftechnik (IWT), Bremen (D)

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A Real Time Radio Frequency Field Imaging for Detection of Impurities in Liquids

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Abstract: The objective of this paper was to detect of impurities in liquid materials. The application of the technique to the assessment of single object and the appropriate starting material is discussed. Basic theory will be used to show how the high frequency field imaging is transformed into a time varying charge distribution at three transducer faces. It will also be shown that this gives a critical assessment of the factors limiting the performance of this transducer. The donor density is assumed to be variable of the coordinates. This transducer will be used as a radio frequency photo sensor device in an optically scanning system, to improve the quality of imaging. This invention can detect accurately the impurity contents of unknown object in refined metallurgical Grease liquids (such as glycerol and glycerin). A digital signal processing technique is used to improve the quality of image. A digital correction technique will be shown to offer a simple and convention means of eliminating the effects of system non-uniformities. This technique is simple, low-cost and suitable for industrial applications.

Keywords: Image processing and remote sensing.

1. Introduction

A radio frequency photo sensor device package having improved for capable to detect the impurities in liquids. A major part of this work is concerned the design and manufacture of the electronics radio frequency drive and signal processing circuits suitable to give output signals for both qualitative visual images and quantitative records of data obtained from typical samples. In addition, some mechanical design and fabrication of a suitable specimen chamber will be required, including the provision of an optical 2-D laser scanning source and electronic display. A D.C. reverse bias can be produced across the photo sensor device by applying a radio frequency. This has been observed to be roughly proportional to the amplitude of the applied radio frequency signal.

In previous work we have designed a theoretical model of RFT at two dominations and assuming the charge distribution (donor density) is constant. In this paper a large area of high resistivity Ge Schottky photodiode is specially fabricated as a transducer, it is called the High Frequency Transducer (HFT). The semiconductor is the substrate of the HFT and can be divided into two regions [3]. Region I is the depletion region between (x=0, x=d, y=0, y=r). Region II is the neutral region between (x=d, x=d+t, y=r, y=r+s) and both of them are modulated by resistance capacitance (RC) network. For the analysis of the semiconductor layer (i.e. Ge of high resistivity) with a high frequency field (such as Radio Frequency and Microwave) of some volts, the under depletion approximation charge distribution N is assumed function of the coordinates (x, y). The potential distribution in the depletion region of Schottky barrier junction depends upon its spatial frequency k, the applied voltage, and the Ge resistivity and permittivity.

2. Theoretical Modelling

We would have to solve the second order partial differential equation in three dimensions given appropriate boundary conditions. However, since any distribution of high frequency potential or field in y-dimension can be synthesized by means of an infinite sum of terms of different spatial frequency k= 2π/λs, we choose to find a specific solution for a single spatial frequency. The three dimensional model shown in Fig. 1, will be used.

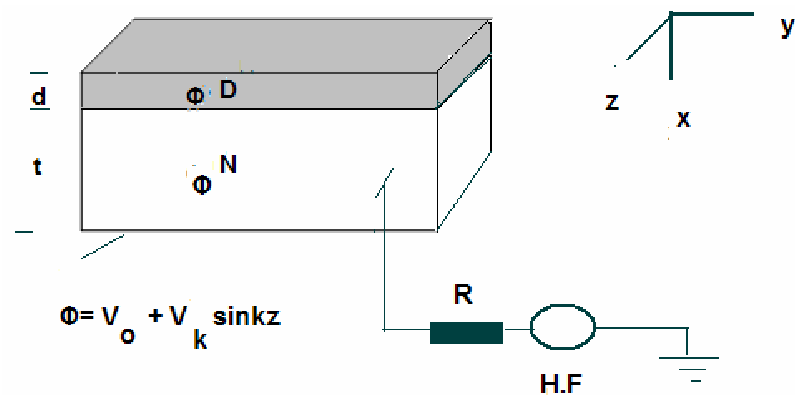

Fig. 1. The 3-D model of High Frequency sensor device.

The applicable equations for the two regions containing electric fields are Poisson's equation [4, 5] for the depletion region;

$$\Phi^D (x, y, z) = c\ f(x, y) \tag{1}$$

And Laplace's equation [6] for the Neutral region:

$$\Phi^N (x, y\ z) = 0, \tag{2}$$

where ϕ^D and ϕ^N are the depletion and neutral potential respectively. A specific solution to equ.1 and equ.2 can be obtained for a spatial frequency k respectively is:

$$\phi^N(x, y, z) = C1 \sinh k(x+y)/ \sqrt{2} \sinh kz + C2\ (xy)^2, \tag{3}$$

where [0 < x < d, 0 < y < r], and

$$\phi^N(x, y\ z) = C_3\ [\exp(k(x+y)/2) + \exp(-k(x+y)/2)]\ \text{Sinh}kz + C_5\ xy + C_6, \tag{4}$$

where d < x < t+d, r< y < r+s.

C_1, C_2, C_3 are the constants and C_4, C_5, C_6 are the potential amplitudes. The following boundary conditions are used to solve Eq.3 and Equ.4.

(i) Φ^D (x, y, z) = 0, at x = 0, and y= 0.
(ii) Φ^D (d, r, z) is continuous at x=d, y= r.
i.e. Φ^D (d, r, z) = Φ^N (d, r, z)
(iii) The total current is continuous at $x=d$. and $y = r$. i.e. $M\ d\phi^D/dx = d\phi^N/dx$.

$$M = \frac{\delta^D + j\omega\varepsilon}{\delta^N + j\omega\varepsilon},$$

δ^D = The conductivity of the depletion region
δ^N = The conductivity of the neutral region
ε = The permittivity of Germanium material

(iv) Φ^N(d, r z) = Vo+ V_kSinkz, where x = d + t=d, and y = r + s = r

V_o = the constant potential uniform with respect to z
V_k = the external ac voltage produced by high frequency source with spatial frequency k.

From equ.1, equ.2, and relation (ii), we obtained;

$$C_1\ \text{Sinh}kl = C_3 \exp k\,l + C_4 \exp -k\,l \tag{5}$$

and

$$C_2\ l_2 = C_5\ l + C_6 \tag{6}$$

where

$$l = d + r/\sqrt{2},\ l = rd/\sqrt{2}$$

From equ.1, equ.2, and relation (iii), we have;

$$MC_1\ \text{Cosh}kl = C_3 \exp k\,l - C4 \exp -k\,l \tag{7}$$

and

$$3MC_2\ l_1 = C_5 \tag{8}$$

From equ.2 and relation IV, we have

$$C_3 \exp(kl_2) + C_4 \exp(-kl_2) = V_k \tag{9}$$

and

$$V_o = C_3\, l_3 + C_6$$

where L_2 = d+ s+ r+ t = l+ s+ t = (d1+ r1)/√2, l_3= (d + t) (r + s) =d1r1

Solving the above equations, the constant values are evaluated. See Table 1. Substituting these values in equ.1 and equ.2. We obtained the final solution.

Table 1. Constants.

$$C_1 = V_k / \text{Sinh}kl\cosh k_m (1+M \tanh k_m \coth kl)$$

$$C_2 = V_k [1+ \omega (1- l_1)] / l_1^2 (1+ \omega)]$$

$$C_3 = \frac{V_k \exp\text{-}kl\, (\tanh kl+M)}{2 \sinh k_m (M+ \tanh kl \coth k_m)}$$

$$C_4 = \frac{V_k \exp kl\, (\tanh kl - M)}{\text{Sinh} k_m (M+ \tanh kl \coth k_m)}$$

$$C_5 = 2MV_o l_1 / (l_1 + \omega)$$

$$C_6 = V_k [l_1\ (1\text{-}2M) + \omega] / (l_1 + \omega)$$

The theoretical analysis described above has been used determine the behaviour of a high frequency sensor of the type sketched in Fig. 1. Using the solution of Passion's and Laplace's equations on 3-D has been found which permits reduction of the potential amplitude distribution as a function of the spatial frequency and the characteristics of the photoconductivity semiconductor layer.

Fig. 2 shows the potential amplitude in the depletion region of the HFT as a function of the spatial frequency k from this graph, it is apparent that the potential amplitude related to various parameters such as Ge resistivity and high frequency as shown in Fig. 3, and Fig. 4, respectively.

These plots suggest that the highest potential amplitude is obtained when the Ge resistivity is high and for operation at higher frequencies.

2. Experimental Set-Up

In this work, grease (glycerol, glycerin) were used as a dielectric liquids, the dielectric constants being 30 and 50 respectively. Fig. 5 has shown the electronic system and Fig. 6 shown the package, in which the liquid is contained inside a rubber ring. The inner diameter of the ring is 2 cm and the outer diameter 4 cm, with the thickness 2 mm. This ring is placed on top of the metal ground plate and the grease was filling the interior area. A piece of polythene in the form of a triangle object (1/2 cm, 1/2 cm, 1/2 cm) and 1 mm in thickness is inserted in the grease as an impurity object. During the work detailed calculations have been completed to determine the optimum frequency and drive level required for the optical sensor device with typical values of conductivity and permittivity [3]. As a result it has been decided that a signal frequency will be used initially, around 29.5 MHz for glycerol and 12 MHz for glycerin, with an output level of about 10 volts peak into a load of 100 Ohms.

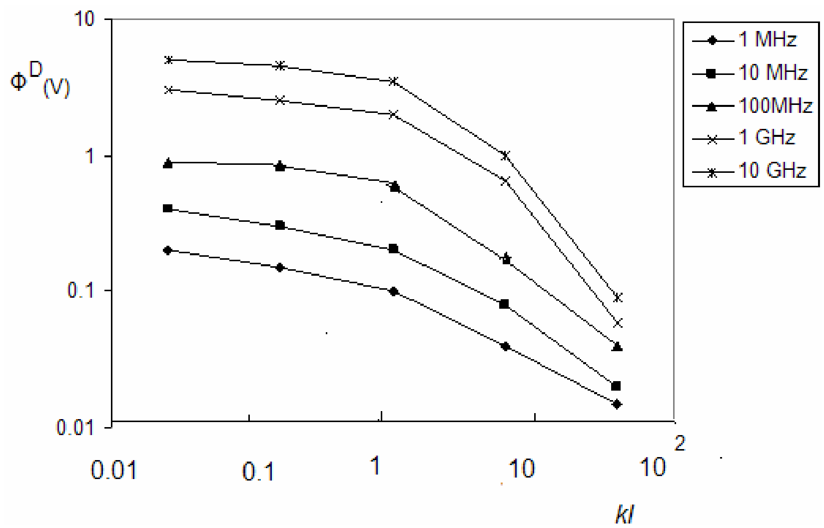

Fig. 2. Te Variation of Φ with the Spatial frequency k at various High Frequencies.

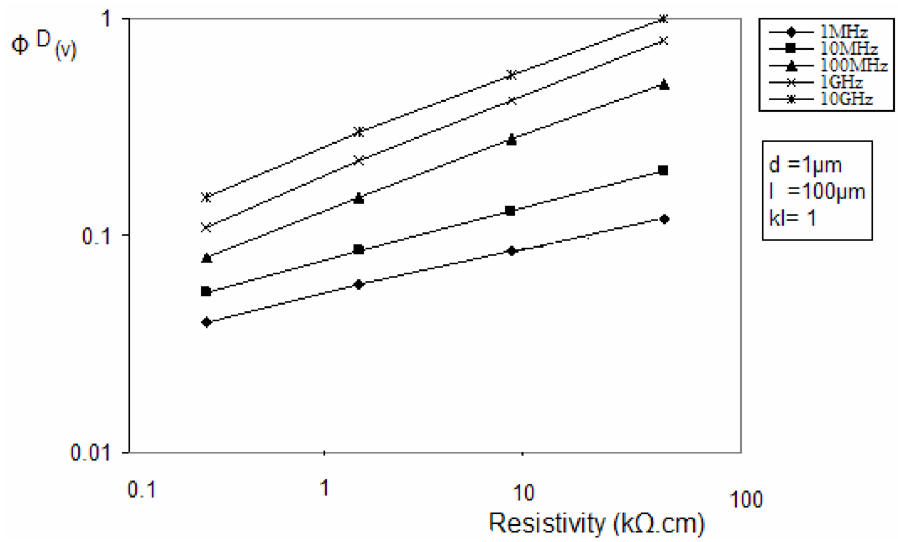

Fig. 3. Variation of Φ^D with Resistivity of Ge material at various High Frequencies.

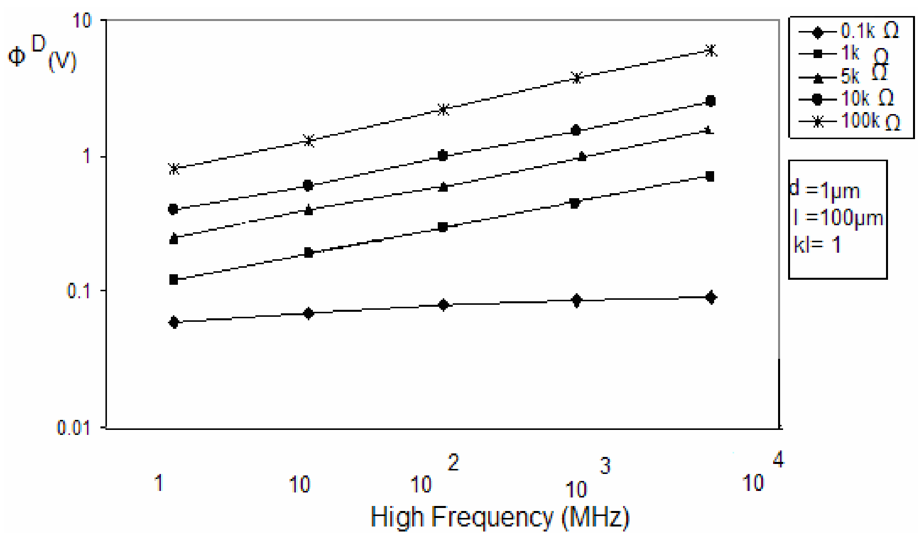

Fig. 4. Variation of Φ^D with High Frequency for different material resistivities.

Using this assumption the design of the input stages of the signal processing circuits for the photovoltaic output at 50 kHz has been initiated. The system is an ideal application for the use of a look-in amplifier, since a reference signal at 50 kHz is used to modulate the scanned optical beam. The modulated r.f. drive has been used in a place of the presently favored C.W. drive. The potential advantage achievable from this approach would be a reduction in drive level, leading simple signal processing and a lower requirement for r.f. drive power.

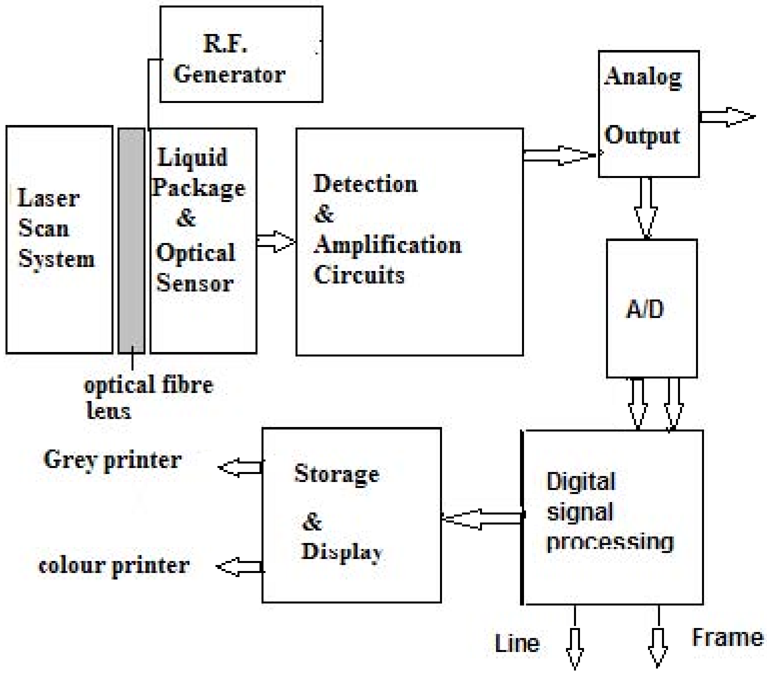

Fig. 5. The radio frequency field image system block diagram.

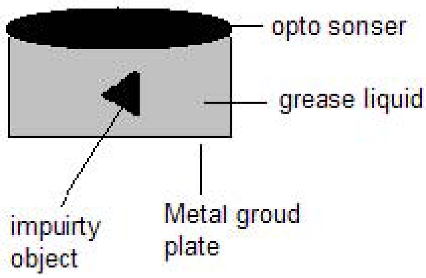

Fig. 6. Package of liquid and the optical sensor.

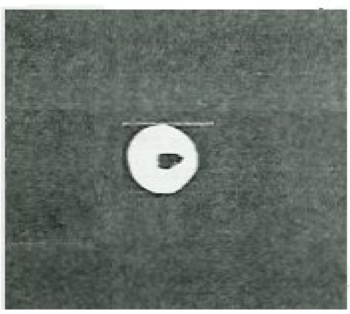

Fig. 7. The photograph of r.f image showing the impurity object.

3. The Results and Discussions

Analog radio frequency image of the object are shown in the Fig. 8. Also the line scan and colour coded images were shown in Fig. 9 and Fig. 10 respectively. The frequency was 29.5 MHz for glycerol and 12 MHz for glycerin and the light modulation frequency was 50 KHz. The useful outcome of this work is to show the effect of varying dielectric constant on the enhancement of the photovoltaic output under the influence of a radio frequency field. It was difficult to see a different between the glycerol and glycerin radio frequency images because the very enhancement of photovoltaic signal has resulted in each case. The difference was apparent in the gain, for example, at radio frequency potential or 20 volts across the glycerol and glycerin packages. The photovoltaic gains were 28 dB and 25 dB respectively.

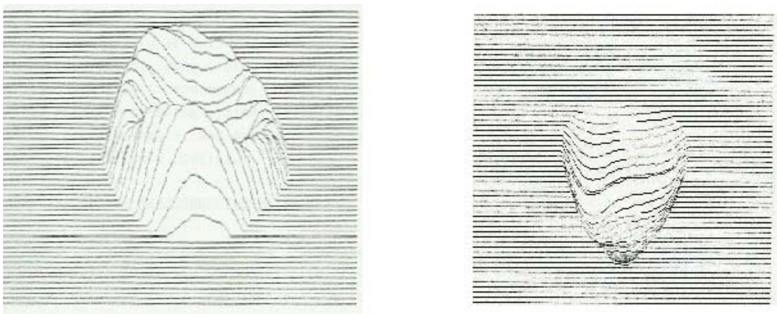

Fig. 8. The photograph of r.f image showing the impurity object.

Fig. 9. The colour coded r.f image of the impurity object.

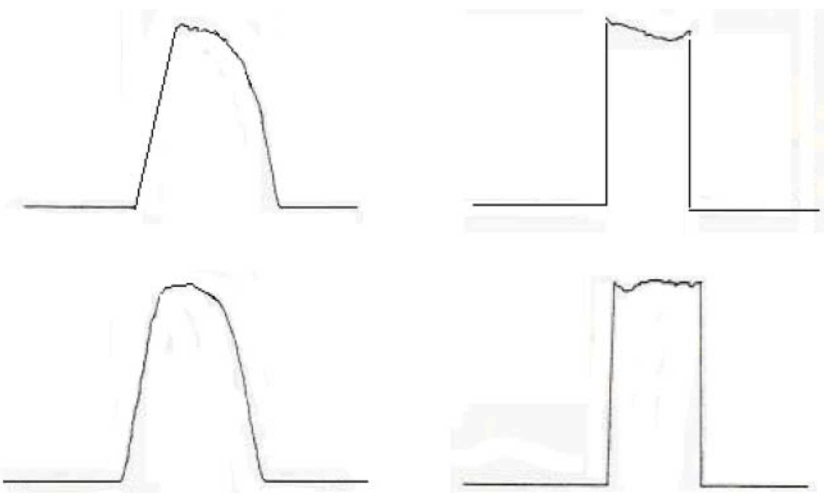

Fig. 10. Line-scans before and after correction.

The digital image correction technique [4, 5] has been used for removing the effects of the non-uniform response of the sensors. Fig. 10 shows the amplitude of r.f image line scan (i.e. 33, 44) of the impurity object and the corrected line after applied the correction technique.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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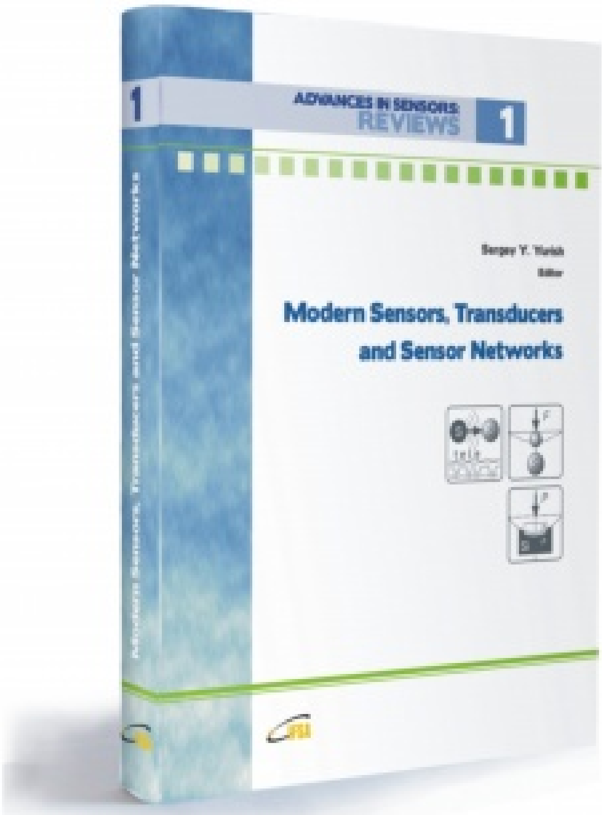

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