INVESTIGATION of ELECTRONIC MEASUREMENT SYSTEM for CHARACTERIZATION of GLASS MEMBRANE

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Abstract

An electronic method for characterization of glass membrane has been indigenously investigated in the present work. Glass membrane is widely used as a sensing material in the potentiometric sensors. The performance of potentiometric sensor mainly governed by the physical characteristics of glass membrane. In the present work, simple electronic circuit has been developed for the measurement of electric and dielectric properties of glass membrane. The prototype circuit is assembled by use of locally available low cost components on general purpose PCB. Characteristics measured with the help of it are in the vicinity of the expected values. The present work is helpful to the glass blowers and instrument designers for the diagnosis of glass membrane based potentiometric sensors.

Keywords: *Glass membrane, dielectric constant, electrical resistance, potentiometric sensor*

1. Introduction

Glass is a super-cooled liquid which is non-crystalline substance generally found in solid state [1, 2,]. The ordinary glass, commonly known as soda lime glass is a mixture of SiO_2, Na_2CO_3, NaOCaO and many other additives at trace level [3]. In addition to this type of glass there are many other types which are given in table 1.

Table 1: Common types of Glass

Sr. No	Type	Composition	Characteristics	Uses
1	Soda lime glass	Na_2CO_3,SiO_2, NaOCaO	High thermal expansion, Low resistance to heat	Bangles, Window glass Incandescent light bulb
2	Quartz silica glass	SiO_2	Low thermal expansion, high resistance to heat	Jewellery and Furnace tube Picture tube of TV
3	Crystal glass	SiO_2, PbO, K_2O, Na_2O, Zno, Al_2O_3	High refractive index, high elasticity	Glassware
4	Alumino Silicate glass	SiO_2,Al_2O_3,CaO , MgO, BaO,B_2O_3	High resistance to water erosion	Fibre Glass, Halogen bulb

5	Sodium borosilicate glass	SiO_2, Na_2O, Al_2O_3, B_2O	Dimensionally stable	Laboratory and cooking glass ware
6	Germanium oxide glass	Al_2O_3, GeO_2	Low optical density	Fibre optic waveguide

Structure of glass is continuous random network as described by Zachariasen [5], where silicon atoms are connected by bridging oxygen atoms. In addition to the characteristics mentioned in table 1, more or less any glass has common characteristics such as fragile-ness, optical transparency, high composition density. Glass is a bad conductor of heat and electricity but its other properties are unique as given in table 2. Properties of glass indicated in table 2 are unique and rarely found in any other substance.

Table 2. Properties of glass membrane

Property	Typical value
Transmissivity	>90%
Reflectivity	>4%
Chemically inert	Insoluble
Anticorrosive	High resistance to contamination
Tensile strength	~7000 PSi
Electrical resistance	~ 100 MΩ
Dielectric constant	~ 5-10

Properties of some glasses e.g. sulphate glass are measured by Sunder and Rao [4] using capacitance bridge method. They have used manually operated laborious capacitance bridge that requires external source of AC signal. Glass has unique properties because of its structure that is shown in figure 1.

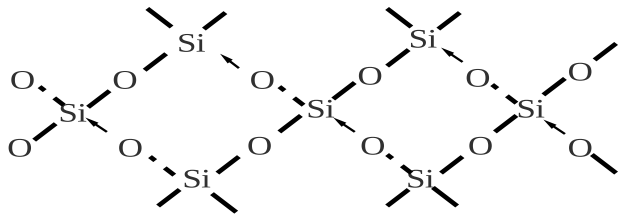

Figure 1.Typical Glass Structure

The glass with less thickness is used as membrane in some Ion Selective Electrodes (ISE). Yoshihiro Abe and Masunobu Maeda[6] have investigated ISE for sodium by use of glass membrane. The performance of such electrodes depends on the membrane properties described by Bakker [7]. Measurement of properties is necessary for improving the performance of electrode. Himanshu Tripathi, et al. [8] have done the study of characteristics of some glasses which are used as bioactive material. In the present work, electronic method for the measurement of characteristics parameters of glass is investigated and its results are reported in this article. The article is divided into following sections: methods are discussed in section 2, experimental work is discussed in sections 3, conclusions are given in section 4.

2. Methods

Glass membrane is an insulating material and hence difficult to measure its characteristics parameters like electrical resistance and dielectric constant. The electrical resistance of insulating substance [9] is generally measured by 'Megger'. It requires high voltage power supply that can spoil the glass membrane sample. In the present work, I have proposed the deflection method which is safe to use for thin glass membrane samples.

2.1 Deflection Method

The diagram of deflection method is shown in figure 2.

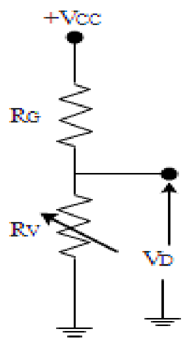

Figure 2. Deflection Method

In this method, voltage V_D is deflected by 90% of applied voltage and calculated with the help of basic laws of electronics such as Ohm's law and Kirchhoff's voltage law (KVL). The V_D is given by Eq. (1).

$$V_D = \left(\frac{R_V}{R_V + R_G}\right) \times V_{CC} \qquad (1)$$

Where R_G and R_V are the resistances of glass and potentiometer respectively, V_{CC} is the fixed DC supply voltage required to fulfil the KVL. This method can be improved by use of buffer amplifier for minimizing the loading error.

2.2. Capacitive Method

Dielectric constant of glass membrane is obtained with the help of RC series circuit as shown in figure 3(a).

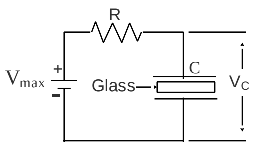

Figure 3(a). Capacitive Response Circuit

In this method glass used as dielectric medium in parallel plate capacitor. The capacitor is charged in RC series circuit and the dielectric constant is obtained from the RC time constant given in Eq.(2),

$$\tau = R \times C \qquad (2)$$

Where, τ is the time required to charge the capacitor up to 63% of V_{max}. The charging of capacitor is shown in figure 3(b).

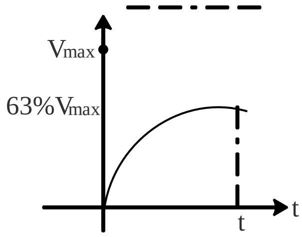

Figure 3(b). Charging of Capacitor

Deflection and capacitive methods are simple to construct, but the observations are taken manually can introduce the measurement errors.

3. Experimental Work

Above two methods are combined in the proposed circuit of free running oscillator using IC 555 [10] as shown in figure 4.

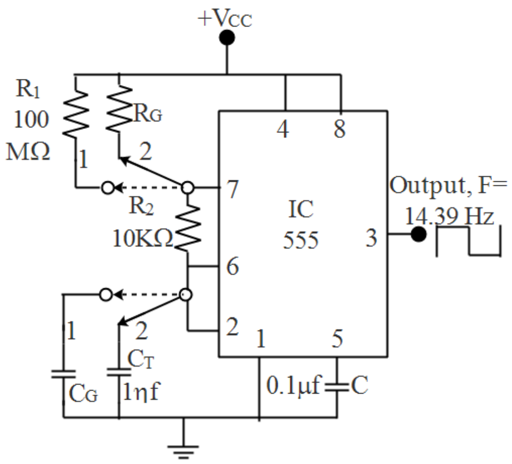

Figure 4.Electronic Method for the Measurement of Resistance and Dielectric Constant of Glass Membrane

To measure resistance of glass (R_G), the DPDT switch is placed at position 2. The circuit generates square wave with frequency F_R [10] given by Eq. (3),

$$F_R = {}^{1.44}/_{(R_G+2R_2)C_T} \qquad (3)$$

Eq. (3) is rewritten to find the value of R_G which is given by Eq. (4),

$$R_G = \left({}^{1.44}/_{F_R \times C_T} \right) - 2R_2 \qquad (4)$$

To find the value of dielectric constant (K_G), place the switch at position 1 and measure frequency with the help of oscilloscope. Further substitute it in Eq. (5) and Eq. (6) for the calculation of dielectric constant (K_G). The frequency, F_c, measured by oscilloscope is substituted in the Eq. (3) and obtained Eq. (5) as,

$$F_C = {}^{1.44}/_{(R_1 + 2R_2)C_G} \qquad (5)$$

Further, C_G can be obtained by rewriting Eq. (5) as,

$$C_G = {}^{1.44}/_{(R_1 + 2R_2)F_C} \qquad (6)$$

and K_G is calculated by substituting C_G in Eq.(7),

$$C_G=\frac{\epsilon_0\times K_G\times A}{d},\quad K_G=\frac{C_G\times d}{\epsilon_0\times A} \qquad (7)$$

The method shown in figure 4 is used to measure R_G and K_G of different glasses. The measured value of R_G is very high and it is in the range of 100 to 400 MΩ. It varies with the thickness and temperature of glass. The dielectric constant is measured by placing the glass membrane between the two metal plates of capacitor. The measured value matching with the expected value.

4. Conclusions

A glass membrane used in glass electrode has high electrical resistance due to its amorphous and non-ionic nature. The resistance is high due to strong ionic bond between silicon and oxygen atoms of silica material. The absence of free electrons in the glass membrane makes it electrically non-conducting. However, when membrane is used in electronic circuit for the measurement of activity of ions then the circuit should be complete. The circuit will be complete if glass membrane allows electric current either by charge transfer or ion exchange method. Some glasses like corning glass are suitable for ion exchange process with thickness upto 1 mm with resistance of ~400MΩ, allows ion exchange and completes the circuit. It shows response to the activity of hydrogen ions present in aqueous solution and hence can be used as ion sensitive material. The measurement of dielectric constant of membrane is necessary for the development of alternative method to the commonly used method based on Nernst's method.

Future Scope

Present work can be extended for relating the measured values of R_G and K_G with the glass electrode properties such as, response time, accuracy, and precision. They can be used for the diagnosis of the parameters of glass membrane electrodes like as hydration of glass surface, drift, asymmetry and alkaline error.

References

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