Reprinted from

TECHNICAL DIGEST OF THE 11TH SENSOR SYMPOSIUM, 1992. pp. 233 ~ 236

Capacitive Humidity Sensor Using Polyphenol Resin

Kazuhiro SUZUKI, Yo-suke ISHIZAKA, Katsumi INOUE,
Yo-ichi NABETA and Tadao INUZUKA*

TO-PLAS
3-17, Sakuragi-cho, Chichibu 368, Japan

**Dept. of Electrical Engineering and Electronics,*
Aoyama Gakuin University
6-16-1, Chitosedai, Setagaya-ku, Tokyo 157, Japan

TECHNICAL DIGEST OF THE 11TH SENSOR SYMPOSIUM, 1992. pp. 233 ~ 236 I1-8

Capacitive Humidity Sensor Using Polyphenol Resin

Kazuhiro SUZUKI, Yo-suke ISHIZAKA, Katsumi INOUE,
Yo-ichi NABETA and Tadao INUZUKA*

TO-PLAS
3-17, Sakuragi-cho, Chichibu 368, Japan
**Dept. of Electrical Engineering and Electronics,*
Aoyama Gakuin University
6-16-1, Chitosedai, Setagaya-ku, Tokyo 157, Japan

Capacitive humidity sensors using polyphenol resin (PPR) or cellulose acetate butyrate (CAB) were fabricated. The humidity characteristics of PPR and CAB were investigated in details comparing with each other. Relative humidity (RH) vs capacitance (C) characteristics shows almost linear relationship in the humidity range from 0% to 95.4% for PPR, and shows non-linear for CAB. Hysteresis values against humidity cycles are 0.5% and 3% at maximum in RH equivalent for PPR and CAB respectively. The humidity sensors using PPR work reproducibly after they were kept in RH of 90% for 80C.

1. Introduction

Many kinds of capacitive humidity sensors have been developed. However, they have problems such as relatively large hysteresis against humidity cycles, complicated temperature coefficient for the output signals, slow response against humidity change or relatively large irreversible change of the characteristics, if the sensors have been kept in a high humidity and/or high temperature circumstances etc.. To settle these problems, it is required that the humidity-sensitive material has the fundamental characteristics as follows;[1]

(1)containing hydrophilic groups and hydrophobic groups
(2)non-porous texture
(3)amorphous structure
(4)high phase transition temperature
(5)equal heat of adsorption of water molecule for 1st layer and for Lth ($L \geq 2$) layer
(6)sufficient distance among hydrophilic groups.

It is already reported by several researchers that cellulose acetate butyrate (CAB) is a suitable material for the capacitive humidity sensor.[1-4]

In this work, as a candidate of the humidity-sensitive material, we choose polyphenol resin (PPR) considering the fundamental characteristics described above. However, it is not so significant to compare the humidity characteristics of PPR with the humidity characteristics of CAB which measured by a certain researcher in the past, because the characterization method is not standardized. Then, we have fabricated the capacitive humidity sensors same in shape using PPR or CAB, and have investigated the humidity characteristics measured under a same condition.

2. Experimentals

A structure of the humidity sensors which are used in this experiment has been presented in earlier publications.[5,6] In this experiment, the lower and the upper electrodes are made of chromium. The lower electrodes and the upper electrode are to be 400nm and 200nm in thickness respectively.

A thermo-hygrostat which is used in this experiment is a divided flow type humidity generator of SRH-IR135ADR by SHINEI KAISHA. Temperature control of the lid of the test chamber and the flow of saturated water vapor are improved.

Multi-frequency LCR meter of 4275A by HEWLETT PACKARD is used for capacitance measurements. The capacitance measurements were operated at the frequency of 100K, 200K, 400K, 1M, 2M and 4MHz.

RH-C characteristics were measured at the temperature of 30C and 50C in the relative humidity range from 0% to 95%. Time response of capacitance against humidity change such as 10.7%↔90.7%, 10.7%↔21.2% and 81.2%↔90.7% were measured at the temperature of 30C. Long term stability of the RH-C characteristics in various circumstances were also characterized. Before and after these atmosphere exposures for four weeks the RH-C characteristics at 30C are measured and compared.

3. Results and discussion

The RH-C curve varies slightly with the operation frequency. In the following results, the frequency is selected to minimize the temperature coefficient of RH-C curves for each material.

Typical RH-C curves for PPR measured at the frequency of 200KHz, and temperature of 30C (▲,△) and 50C (●,○) are shown in Fig.1. The curves for CAB38 (butyryl content of 38%) and CAB50 (butyryl content of 50%) measured at the frequency of 2MHz are shown in Fig.2 and Fig.3 respectively. The ratio of the capacitance at 95.4% for 30C ($C_{95.4\%-30C}$) to the capacitance at 0% for 30C ($C_{0\%-30C}$), maximum width of hysteresis against humidity cycles, temperature coefficient and linearity of the curves are summarized in Table 1. The width of hysteresis and the linearity are represented in a difference of RH equivalent.

With regard to the ratio of $C_{95.4\%-30C}$ to $C_{0\%-30C}$, it is the largest for CAB38 and it is the smallest for PPR. By contrast, maximum width of hysteresis is negligibly small for PPR and relatively large for both CAB. The width of hysteresis has a lot of influence on the accuracy of humidity measurement, because it is not compensatable substantially. All temperature coefficients are relatively small. RH-C curves are out of the straight and almost linear for CAB and PPR respectively. From the results, it is considered that complicated electric circuit is not needed for PPR measuring of the relative humidity accurately.

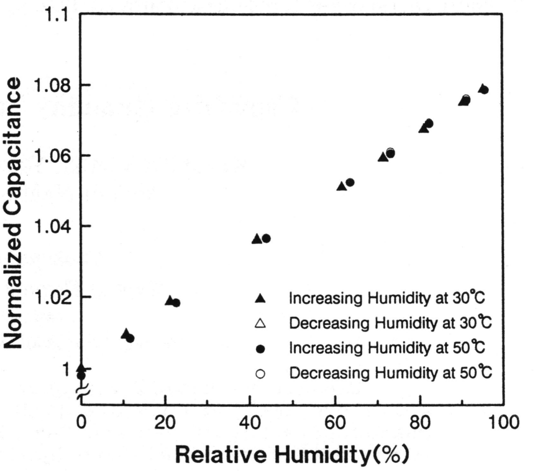

Fig.1 RH-C characteristics for PPR

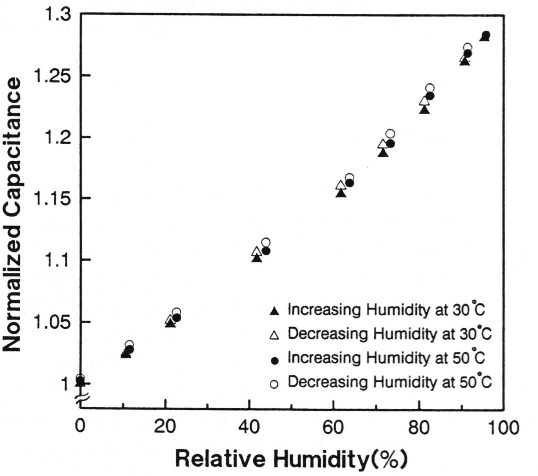

Fig.2 RH-C characteristics for CAB38

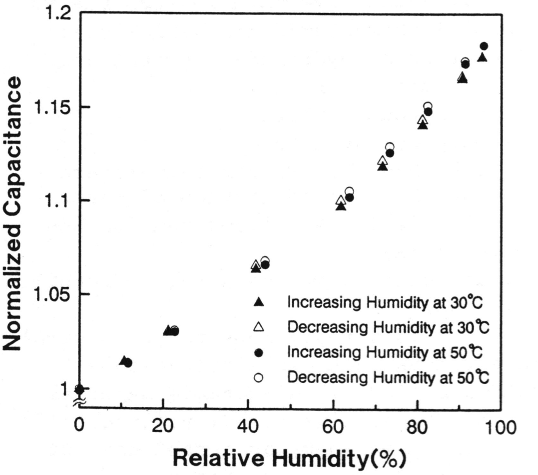

Fig.3 RH-C characteristics for CAB50

Table 1. Fundamental characteristics of RH−C

	CAB38	CAB50	PPR
$C_{95.4\%-30C}/C_{0\%-30C}$	1.282	1.177	1.079
maximum hysteresis (%)	3.0	2.0	~0.5
temperature coefficient (%/℃)	0.08	0.1	−0.1
linearity (%)	±5.0	±4.5	±1.0
operation frequency (Hz)	2×10^6	2×10^6	2×10^5

Table 2. Response time for humidity valiatiation (corresponds to ±1% error in RH equivalent)

humidity variation	CAB38	CAB50	PPR	test chamber
10.7%→21.2%	<1	<1	<1	0.81*
21.2%→10.7%	1	<1	<1	0.81*
81.2%→90.7%	33	28	4	0.77*
90.7%→81.2%	9	6	12	0.77*
10.7%→90.7%	35	25	12	1.50*
90.7%→10.7%	6	10	4	1.50*

unit (min) * means calculated value

Table 3. Stability of RH−C characteristics in valious circumstances

circumstance	CAB38	CAB50	PPR
~0% at 100℃	−2	×	5
~0% at 80℃	−2	×	−1
~0% at 30℃	−1	1	−1
~0% at −24℃	1	1	1
~90% at 80℃	×	×	3
~98% at 30℃	2	3	2
~100% at −24℃	1	2	1
water dipping at RT	3	−3	−1
the outdoors	2	1	−1
the indoors	−1	1	−2
benzol (2500ppm)	−1	1	−5
methyl ethyl keton (20000ppm)	3	×	×
2−buthanol (15000ppm)	×	×	5
acetic acid (1000ppm)	2	2	−1
ethyl acetate (40000ppm)	4	×	−3
hydrochloric acid (500ppm)	~0	1	~0
dichloroethane (5000ppm)	~0	1	−1
ammonia (5000ppm)	2	3	1

unit (%) × means <−5% or >5%

Response duration time of capacitance, which corresponds to plus or minus 1% error in RH, against humidity variations are shown in Table 2. Calculated response duration time of humidity changing in the test chamber for plus or minus 1% error in RH to the set point are also shown in Table 2. The calculations were made on the assumption of the diffusion velocity of air is fast enough.

The response time, which corresponds to plus or minus 1% error in RH, is about 1min at most in the lower humidity range (<21.2%) for all materials. However, it takes more duration time for the higher humidity range. If it defines the comprehensive response time as the maximum response time in Table 2, it is 12min, 33min and 28min for PPR, CAB38 and CAB50, respectively.

Long time stability of RH-C characteristics is shown in Table 3. The values were calculated from the maximum irreversible change of capacitances. The concentration of all organic compounds, HCl and NH_3 is 100 times of threshold limit[7-8] values for mankind.

It is found that the humidity sensors by PPR work more stable in RH of 90% at 80C circumstance than the sensors by CAB.

4. conclusion

The humidity sensors by polyphenol resin are better than the sensors by cellulose acetate butyrate in the sense of the hysteresis and linearity of RH-C characteristics, time response against humidity change and also the stability at a high temperature and humidity circumstance.

References

1) K.Suzuki: T.IEE Japan in progress
2) T.Sashida, K.Motosugi, K.Akaba and M.Kawarai: Kobunshi Ronbunshu, 46 (1989) 499
3) Y.Sadaoka, M.Matsuguchi, Y.Sakai and K.Takahashi: J.Mater.Sci.Lett., 7 (1988) 121
4) P.E.Thoma: U.S.Patent 3,582,728
5) K.Suzuki, K.Koyama, T.Inuzuka and Y.Nabeta: Proceedings of 3rd Sensor Symposium, (1983) pp251-256
6) K.Suzuki, Y.Ishizaka, Y.Nabeta and T.Inuzuka: Proceedings of 8th Sensor Symposium, (1989) pp271-274
7) Nihon Kagakukai: "Kagaku-binran" (1973) Maruzen
8) T.Asahara, N.Tokura, M.Okawara, J.Kumanotani and M.Senoo: "Yozai-handobukku" (1979) Kodansha