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Development of solid state sensor by using $CuMoO_4$ – CuO and electronic circuit for digital display of humidity

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ABSTRACT

In this work electronic sensor kit by using ADC 0804 was designed to measure the Relative Humidity values in binary form at various humidity surroundings. Then the Electronic Sensor Kit was connected with digital display circuit the respective humidity values are displayed in two digits decimal form**.** To ensure the measured humidity values by using this circuit, experimentally humidity values are measured on ceramic oxide composite namely **C**u**M**oO_4 – **C**u**O** (CMCO) at various doping percentage.

Keywords: **ceramic matrix composites, electrical properties, oxides**

1. INTRODUCTION

In recent years, the use of humidity control in production processes and products in a wide range of industries, like manufacturing electronic devices, precision instruments, textiles and agriculture has gained momentum momentum (Yeh YC, 1992; Mabrook, 2001; Jingwen Qian, 2016). Sometimes. Sometimes it is necessary to monitor the absolute humidity, or the dew point, but more often it is important to control the relative humidity (RH). Many molybdates and oxides containing transition metal ions show semi conductive behaviour.

The doping of a semiconductor leads to an n- type semiconductor and thus this property is made use of in humidity sensing. Sensing principles applied in humidity sensors are resistive, capacitors, optical, acoustic and piezoelectric etc., etc., (Edwin,2001; Manivannan,2014; Kan-Sen Chou,2016). Materials used in humidity sensors exploiting variations of electrical parameters were roughly classified into three groups: electrolytes, organic polymers and ceramics ceramics (Morimoto,1969, Matsuguchi,1991; Miyazaki,1994; Hashmi,1997; Chou,1999; Youichi Shimizu,2006;). The ceramic metal oxides had shown advantages in terms of their mechanical strength, resistance towards chemical attack and thermal as well as physical stability stability (Dawson,1995; Traversa,1995; Traversa,1995a; Suresh Raj,2002; Pokhrel 2002).

The extensive research work on composites CuO-MoO_4 has been carried out to study the electrical properties and the effects of doping on the humidity sensing properties of transition metal molybdates and standardisation of humidity sensing property of the CuO-MoO_4 by using electronic sensor kit and development of electronic circuit for the digital display of humidity ranges. The aim of the present work is to study the solid state electrical properties of Copper Molybdate. The different composites were prepared by high temperature sintering method and have been tested for sensing characteristics by voltage variation method using the sensor kit.

The output voltage readings were taken from the electronic sensor kit when the samples were kept in the different humidity measuring. From the readings output voltage Vs humidity, calibration graph is drawn. Another electronic circuit was developed and constructed using ADC 0804, LM 356A, CD 411, FND 500 to display the humidity values directly when the output of the electronic sensor kit with the sample is fed as the input to this circuit.

2. EXPERIMENTAL DETAILS

Output voltage measurement using electronic sensor kit for different percentage of humidity: The voltage measurement of the composites was done using our electronic sensor kit sensor kit (Sherin,2007) for different humidity levels which were generated using various buffers. These buffers are saturated solution of hydrated salt and can give rise to humidity levels in closed environment. Controlled humidity environment were achieved using an hydrous saturated aqueous solution of Potassium acetate (CH_3COOK), Sodium nitrite ($NaNO_2$), Barium Chloride ($BaCl_2$) and Copper Sulphate Pentahydrate ($CuSO_4.5\ H_2O$) in a desiccator at an ambient temperature of 25°C, which yielded approximately 22%,51%,79%,98% relative humidity respectively.

The humidity levels were monitored using an independent hygrometer. Conductivity study of metal oxide composites ($CuMoO_4$ – CuO) is carried at in room temperature at different water vapour buffers by applying a voltage of from 200 mV to 1200 mV increased in steps of 200 mV and the corresponding output voltage was measured for all the prepared samples CMCO 82,64,46 (Table 1) are listed in Table 2. The relative humidity was varied and output voltages are observed for six input voltages. From these observed values variation of output Voltage with percentage of Relative Humidity is plotted for all the applied voltage (Figure 1-2). The plot of Relative Humidity Vs Output Voltage shows that variation of Output Voltage with percentage of Relative Humidity is in linear trend.

Digital display circuitry part: By studying the calibration graphs it was found that the sample CMCO- 82, 64, 46 in the input ranges 800 mV – 1200 mV show consistent linear variation of Output Voltage with respect to Relative Humidity. Hence for these samples the analog output voltage for various humidity values ranging from 10% - 100% in steps of 10% were taken from the graphs are shown in figures 1 and 2 for the samples CMCO-82 (Fig.1), CMCO-64 (Fig.2). These values are considered as the analog input voltages for the digital display circuit. The Digital Display Circuit consists of 3 stages, shown in Fig.3. Inverting Amplifier circuit - stage 1, Analog to Digital convertor unit – stage 2 and Seven segment common cathode display of Relative Humidity in two digits decimal Form – stage 3

Working function of ADC in the digital display circuit: The input voltage was applied to ADC 0804 through pin 6. Initially, the A/D Convertor chip was wired in free running mode with a self-clock However, this resulted in an output that looked like a clock as a step function. Next the chip was rewired so that it was being clocked by the function generator. An interesting feature of the wiring schematic was the temporary ground for pin 3 and 5. So that reset microcontroller (μc) switch was connected across this pins. These pins are interconnected to one another, and it was grounded through μc switch. When the switch is pressed for few seconds in order to charge before being disconnected from the ground in order to allow the circuit to function. The system worked best when pin 3 and 5 were connected to and disconnect from ground simultaneously. The given analog value was translated to digital value and it was transmitted through to 8 output pins of ADC.

Seven segment common cathode display of relative humidity in two digits decimal form: The analog value was translated to a digital value. LM 356A with Span (10K) pot was connected through pin 9 of ADC. By adjusting the span pot this unit read the Relative Humidity values in Binary and Digital form. Relative humidity values from 10% to 100 % was displayed by glowing the LED lights in binary form on the Digital trainer kit, for various span Voltages in volts and Resistance in Mega ohms. The seven segment common cathode Display circuit was constructed using CD 4511, FND 500 as shown in Fig.4. Using seven segment common cathode display circuit, the binary form of Relative humidity values are converted into decimal form.

3. RESULTS AND DISCUSSION

The Digital Display Circuit was constructed and the output of the Electronic Sensor Kit is fed as the input to the Digital Display Circuit. The analog inputs are taken from the calibration graphs of the samples CMCO-82, 64 (Figure 1-2) by plotting in graph sheet. And these analog voltages are converted into Decimal Digital form of the Relative Humidity Values by using our own circuit. It is shown for some of the ranges of input voltage in the Tables 3.1, 3.2 for CMCO-82 sample, the last column in these Tables shows the observed Decimal Digital display of Relative Humidity.

The input voltages are taken from the calibration graph (Fig. 1) for the composite CMCO-82 with respect to the input voltage 800 mV and 1000 mV for humidity values 10%-100%. The readings corresponding to the mV less than 100 were marked it as in Table 3 and 4. For these set of readings Relative humidity, Span voltage and Span resistance are also measured. Similarly the readings are taken for other samples and to verify our results the same procedure has to be repeated for all input voltages and are verified.

The first column and the last column show the excellent agreement for the input voltage greater than 100 mV. Since ADC chip gets activated above than 100 mV. For the low input values ADC chip which has low activation voltage has to be used.

In addition, the resistance of the pellet can be determined by using the formulae, $R_F = -V_0/V_{in} \times R_1$. A suitable resistance was connected across R_1 [i.e. Pin R_3 and FE (Free End)] as the input resistance. In our work, 10 MΩ was connected across R_1 as input resistance. The calculated resistance values are given in Table 3.3 for all the samples under study and it is to be found maximum for CMCO-46.

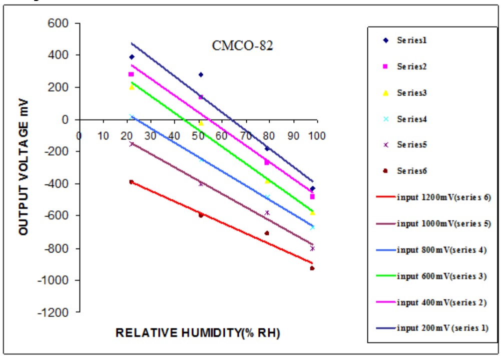

Fig.1.Relative humidity Vs output voltage for various input voltage for CMCO-82

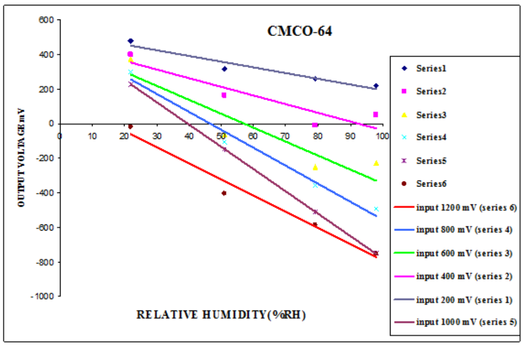

Fig.2.Relative humidity Vs output voltage for various input voltage for CMCO-64

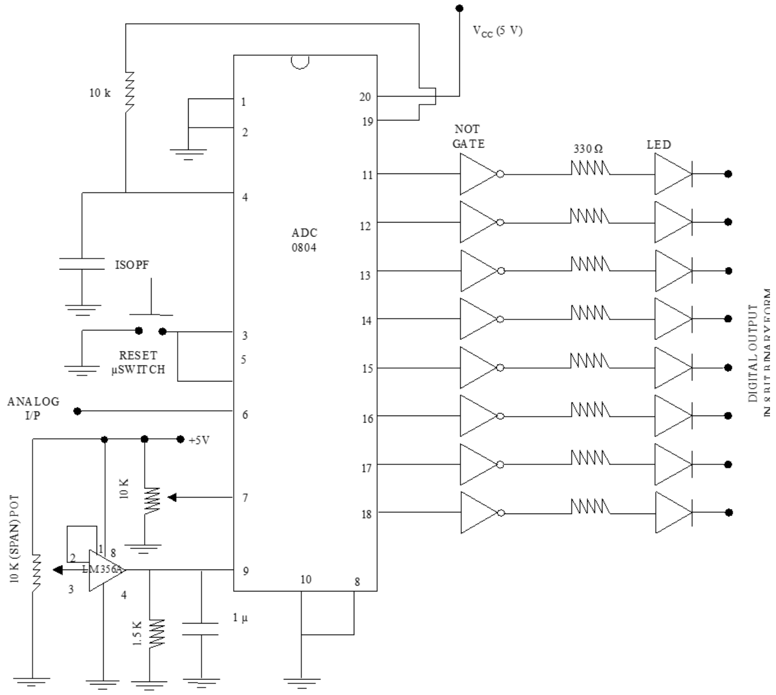

Fig.3.Humidity display circuit in binary form

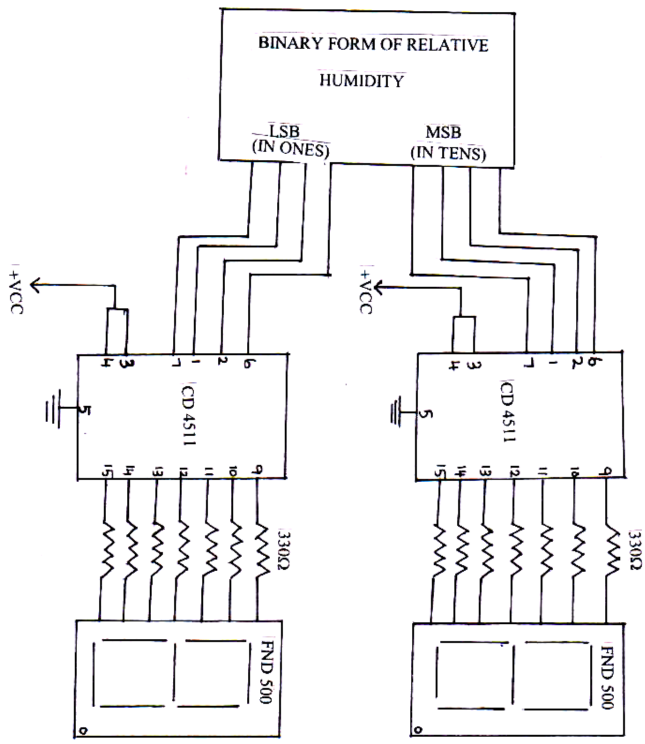

Fig.4.Circuit for digital display of humidity in decimal form

Table.1.Fabrication of cumoo4-cuo composites

Sample code	$CuMoO_4$ (Mole %)	CuO (Mole %)
CMCO 82	80	20
CMCO 64	60	40
CMCO 46	40	60

Table.2.Relative humidity vs output voltage for various input voltage

Composite	Relative humidity (%RH)	Output voltage (mV)					
		V_{IN} = 200 mV	V_{IN} = 400 mV	V_{IN} = 600 mv	V_{IN} = 800 mV	V_{IN} = 1000 mV	V_{IN} = 1200 mV
CMCO – 82	22	390	280	200	20	-150	-390
	51	280	140	-20	-250	-400	-600
	79	-180	-270	-380	-480	-580	-710
	98	-430	-480	-580	-670	-800	-930
CMCO – 64	22	480	400	373	300	230	-20
	51	315	161	-66	-108	-150	-403
	79	262	-11	-253	-360	-512	-585
	98	220	50	-230	-495	-748	-753
CMCO – 46	22	285	160	65	-28	-116	-212
	51	340	200	85	-120	-200	-340
	79	220	-15	-111	-193	-353	-435
	98	222	-14	-252	-485	-514	-865

Table.3.Sample code: cmco-82 input voltage: 800 mv

Standard relative humidity (% RH)	**Input voltage (mV)** (from calibration graph (Fig.1) for Vin =800 mV)	**Span voltage (V)**	**Span resistance (M Ω)**	**Observed humidity (% RH)** (from decimal digital display)
10	130	0. 796	1. 4	10
20	40	-	-	-
30	-50	-	-	-
40	-150	3. 42	-	40
50	-240	0. 68	1. 4	54
60	-330	0. 82	1. 4	60
70	-420	1. 95	2.5	70
80	-510	1. 67	2.1	84
90	-600	2.56	5. 5	94
100	-690	1. 08	1. 5	96

Table.4.Sample code : cmco-82 input voltage : 1000 mv

Standard relative humidity (% RH)	**Input voltage (mV)** (from calibration graph (Fig.1)for Vin =1000 mV)	**Span voltage (V)**	**Span resistance (M Ω)**	**Observed humidity (% RH)** (from decimal digital display)
10	-40	-	-	-
20	-130	1. 7	2 .1	20
30	-220	2.31	3. 8	30
40	-300	4. 99		40
50	-400	2.79	9. 2	50
60	-480	0.901	1. 4	64
70	-560	1.66	2.1	68
80	-650	1.72	2 1	82
90	-730	1.61	1.9	92
100	-820	2.73	8.0	98

Table.5.Relative Humidity vs Resistance

Relative humidity (%RH)	Resistance (CMCO – 82) (MΩ)	Resistance (CMCO – 64) (MΩ)	Resistance (CMCO – 46) (MΩ)
22	10	4	7.14
51	8.33	8.5	14.12
79	6	13.9	5.625
98	8.3	12.5	10.77

4. CONCLUSION

Electronic circuit was designed by using ADC 0804,Cd 4511 and FND 500 to measure humidity values in two digits decimal form and it is ensured on ceramic composite namely $CuMoO_4$ – CuO (CMCO) at various doping percentage and at various inputs. Our own designed electronic circuit with the solid state chemical sensors is able to show the Relative humidity values in any surroundings, by using this Digital Display Circuit.

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