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Analyzing the imprecise capacitance and resistance data of humidity sensors

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ABSTRACT

The classical statistics cannot be applied adequately when the observations of humidity sensing data are imprecise. In this paper, the analysis of humidity sensing data will be presented using neutrosophic statistics. We present the neutrosophic statistical analysis for capacitance and resistance data of humidity sensors. We collected the data and analyzed it using neutrosophic statistics and classical statistics. From the study, we observed the capacitance and resistance variance of humidity sensors with respect to change in relative humidity. From the comparative study, it is noted that the neutrosophic statistics is more informative, flexible, and adequate in analyzing the imprecise humidity sensors data.

1. Introduction

Accurate detection of humidity and humidity control has been gotten importance in the manufacturing of pharmaceuticals, electronics devices, meteorology, and chemical industries [19,33]. This thing has increased the importance and use of humidity sensors at the commercial level. Different materials are used in the fabrication of humidity sensors. Nowadays, the use of organic semiconductors in the fabrication of humidity sensors has gotten importance because of their extra-ordinary electric properties like intrinsic property, electrical characterization, and low dielectric permittivity [18,22]. Numerous transduction methods have been used in the fabrication of humidity sensors such as field-effect-transistor, surface-acoustic wave optical, capacitive and resistive transduction with their own performance [15,21,24,31]. But capacitive transduction in the fabrication of humidity sensors has gotten importance due to its properties like a linear response, low power degeneracy as well as low cost-effective and much more [25]. It is estimated that there are about seventy-five percent humidity sensors available in market based on capacitive transduction. Similarly, resistive transduction has been also used in the fabrication of many humidity sensors [24]. Researchers are working on different organic, inorganic and composite semiconductors materials and using them in the fabrication of humidity sensors. The humidity sensors fabrication with high stability, high sensitivity and sharp response, as well as recovery, is always desirable. Moreover, a good, effective & ideal sensing layer that may be based on single material or composite which should not be peeled or swelled as it absorbs the relative humidity RH, is an essential requirement [17]. Now let's see some previous works on the fabrication of humidity sensors. Chani et al. [12] used aluminum phthalocyanine chloride sensing thin films of 50 nm and 100 nm, deposited between aluminum electrodes in the fabrication of a surface-type resistive humidity sensor. Similarly [1], used NiPcTs composite organic semi-conductor sensing thin film in the fabrication of surface-type humidity sensors. They characterized its electric properties for both capacitive and resistive transduction. A poly[2-methoxy-5-(2–3 ethylhexyloxy)-1,4-phenylenevinylene]: polyvinylpyrrolidone (MEH-PPV: PVP) composite sensing thin film was used by [11]. They characterized it as surface-type humidity sensors based on capacitive transduction. Also, [30] used PLA sensing film for the fabrication of humidity sensors. They also characterized its electric properties for capacitive transduction.

Generally, it is observed that numerous statistical methods are used to analyze the measured data of humidity sensors. From the best of our literature review, it is found that most researchers have used classical formulas and graphs for these purposes. But such types of analysis only provide information accurately when data is a fix-point value means there is only a single value at a specific value of relative humidity. If there is interval data then all classical methods fail to analyze it accurately. For analyzing such interval data, F. Smarandache introduced a novel statistical method named: Neutrosophic Statistics Method [27]. It is a more flexible and reliable method to analyze the interval data as

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compared to all other statistical methods like the classical method and fuzzy method. The use of the neutrosophic method to analyze the data variance has been gotten importance such as in medicine for the analysis of diagnosis data [32], in applied sciences for the analysis of different data problems [16], in astrophysics for studying the variance of wind data [9], in material science for analysis of resistance of conductors [3], and others. Also, Muhammad Aslam has developed different techniques under the neutrosophic approach [7,8]. Neutrosophic analysis of interval data is associated with an indeterminacy interval for each specific interval to express the variance of data [10]. But the classical method follows the fix-point values data and fails to explain the indeterminacy or variance of data. The benefits of the neutrosophic approach over the classical approach can be seen in the following references [2,13,14,28]. More applications of DSmT for information fusion can be seen in Ref. [29].

The following work is concerned with the use of the neutrosophic method in the analysis of capacitance and resistance data of the humidity sensors as can be seen in our previous work [2]. In this work, we have enhanced our previous work by using the capacitance and the resistance of five humidity sensors based on different materials and explaining the method of analysis of classical and neutrosophic statistics for data. Basically, through this work, we have tried to develop an application of material statistics (a study in which material properties data is analyzed through different methods of statistics) for humidity sensors data based on modern statistics methods. It is expected that our work will be more flexible and informative than previous literature.

2. Data collection

In the following work three humidity sensors have been used which are based on different sensing thin films deposited between different electrodes (shown in Fig. 1) i.e. methyl red thin film between silver electrodes (Ag/MR/Ag), tetra phenyl porphyrinato nickel (II) thin-film between aluminum electrodes (Al/TPPNi/Al), a composite thin film of copper oxide nanopowder and poly-*N*-epoxypropylcarbazol between silver electrodes (Ag/ Cu_2O-PEPC/Ag).

In this work, we have only studied the capacitance and resistance variance with respect to change in relative humidity of said sensors, for the fabrication and other characterizations see the following references [18,5,6]. According to these references, the capacitance and resistance of sensors have been measured through the LCR meter in a chamber at room temperature by varying relative humidity from 15 % to 85 % with the help of a humidifier at the room temperature of about 20 °C with normal atmospheric level. Moreover, the temperature inside the chamber is the same as in the outside atmosphere (We have not measured data experimentally, but by reading the graphs of the above references). The variance of capacitance and resistance of sensors have been studied at 1 kHz with a constant input of 1.0 V as shown in Fig. 2.

Refs. [5,6,18] conducted the experiment for above mentioned sensors. They used the LCR meter for measuring the capacitance and resistance. They used single determinate values to express the capacitance and resistance variation with respect to relative humidity (RH). Refs. [18,5,6] might be used average values or pick the values at which the variation is very low for capacitance and resistance of humidity sensor. Recently, Refs. [2,20,23,26,3,4] argued that the data obtained from the LCR meter do not have the exact observations i.e. at a specific point there a minimum nd maximum point for a data variation. This variation may be small or high. So, The measurement data from the LCR meter should be expressed in intervals rather than the exact values. Therefore, we have collected the data from reading the graphs of Refs. [18,5,6] with the aid of graph reading tools like interval data graph reader and have expressed data in interval based on some theoretical assumption (like at initially there is high variation in the value of resistance). As the data is interval, so the classical method and graphs are not suitable for analysis of data. In such cases, when the actual measurements of humidity sensors are in intervals, the use of classical statistics may mislead the decision-makers. By following [2], we will present the analysis of the data using neutrosophic statistics.

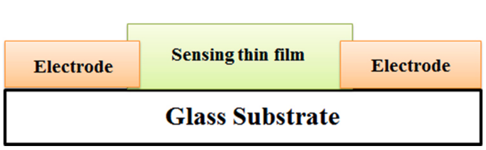

Fig. 1. Schematic pic of sensors.

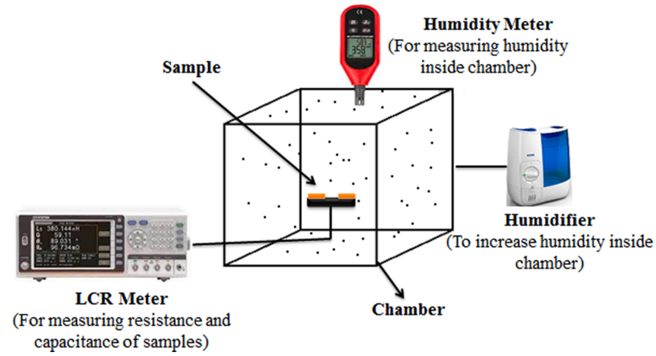

Fig. 2. Electrical characterization setup.

3. Methodology

For the analysis of the data, we have used two statistical methods i.e. classical and neutrosophic methods. The discussion on these methods is as follows:

3.1. Classical method

As the classical method deals with fix-point values, so all intervals of capacitance and resistance have to convert into fixed point values by taking the average formula. Let $X_{Ni} \quad \epsilon[X_{Li}, X_{Ui}]$ is an interval then the classical formula can be written as:

$$X_{Ni} = \left(\frac{X_{Li} + X_{Ui}}{2}\right) \text{i} = \quad 1, \quad 2, \quad 3, \quad 4 \ldots \text{n}_N \tag{1}$$

Classical algorithm for computer programs:
Step 1: Start program.
Step 2:Enter all intervals (whether in table form or manually).
Step 3: Start loop from$i = 1$*to* $i <= n_N$.
Step 4: Execute formula: $X_{Ni} = \left(\frac{X_{Li}+X_{Ui}}{2}\right)$ *(for each interval)*. Calculate and draw a graph.
Step 5: Increment ++ and go to step 3.
Step 6:End internal loop.
Step 7: End program.

3.2. Neutrosophic method

For the neutrosophic method, we have to develop a neutrosophic formula [2,3]. First, we develop a formula for the capacitance analysis of sensors. Let $C(\%RH)_N$ (as capacitance and resistance depend on the relative humidity) is a neutrosophic variable for capacitance with $C(\%RH)_N\epsilon[C(\%RH)_L, C(\%RH)_U]$ a measured interval of capacitance at specific relative humidity %RH. Here $C(\%RH)_L$ and $C(\%RH)_U$ are the lower and upper values of the interval, respectively. So, the neutrosophic formula for capacitance with indeterminacy $i_N\epsilon[i_L, i_U]$ can be written as:

$$C(\%RH)_N \quad = \quad C(\%RH)_L \quad + \quad C(\%RH)_U i_N; i_N\epsilon \quad [i_L, \quad i_U] \tag{2}$$

Basically, the above formula of is $C(\%RH)_N\epsilon[C(\%RH)_L, C(\%RH)_U]$ is an extension of the classical. The equation is containing two parts i.e. $C(\%RH)_L$ determined & $C(\%RH)_U i_N$ indeterminate part. Moreover, $i_N \epsilon [i_L, i_U]$ is known as an indeterminacy interval. For neutrosophic formula $i_L = 0$ and i_U can be found by using$(C(\%RH)_U - C(\%RH)_L)/C(\%RH)_U$. Similarly, for resistance of sensors R(%RH) can be written as:

$$R(\%RH)_N = R(\%RH)_L + R(\%RH)_U i_N; i_N \epsilon \quad [i_L, \quad i_U] \tag{3}$$

Neutrosophic algorithm for computer programs:
Step 1: Start program.
Step 2: Enter all intervals (whether in table form or manually).
Step 3: Start the main loop from $a = 1 to\ a <= n_N$.
Step 4: Calculate $i_U = \left(\frac{C(\%RH)_U - C(\%RH)_L}{C(\%RH)_U}\right)$ (For capacitance).
Calculate $i_U = \left(\frac{R(\%RH)_U - R(\%RH)_L}{R(\%RH)_U}\right)$ (For resistance).
Step 5: Start internal loop $i_L = 0 to i_L <= i_U$.
Step 6: Calculate.
$C(\%RH)_N = C(\%RH)_L + C(\%RH)_U i_N; i_N \epsilon [i_L, i_U]$ (For capacitance).
$R(\%RH)_N = R(\%RH)_L + R(\%RH)_U i_N; i_N \epsilon [i_L, i_U]$ (For resistance).
Step 7: Increment of specific value (for interval loop, here we use 0.05) and go to step 5.
Step 8: End internal loop.
Step 9: Increment ++ and go to step 3.
Step 10: End main loop.
Step 11: End program.

4. Result and discussion

In this work, we focused only on the analysis of the capacitance and resistance variation with respect to change in the relative humidity for humidity sensors. The collected data of capacitance and resistance for all humidity sensors are expressed in Tables 1 and 2.

4.1. Analysis of capacitance and resistance

Now let us move to the analysis of the data. First, we analyze the data of capacitance and resistance through the classical method as shown in Tables 3 and 4, then the neutrosophic method as shown in Tables 5 and 6.

Tables 3 and 4 are expressing the classical analysis of the capacitance and resistance data of the sensors by applying the classical formula of the mean. From the tables, it is seen that classical analysis has converted all intervals into fi- point, which are not defining the variance of the interval from minimum to a maximum value. We have gotten only a single value of capacitance and resistance against specific relative humidity. This is showing that classical analysis is not reliable in making decisions and in concluding the solution to the problem. Similarly,

Table 1
Capacitance of all sensors with respect to change in relative humidity.

Relative Humidity %RH	Ag/MR/Ag Capacitance pF	Al/TPPNi/Al Capacitance pF	Ag/ Cu_2O-PEPC/Ag Capacitance pF
15	[74,82]	[80,89]	[0.9, 1.1]
20	[81,90]	[86,95]	[1.1, 1.2]
25	[100,113]	[91,102]	[2.7, 3.0]
30	[127,144]	[92,105]	[2.8, 3.2]
35	[160,182]	[100,113]	[3.8, 4.2]
40	[181,204]	[107,120]	[4.7, 5.3]
45	[220,250]	[128,145]	[5.3, 6.0]
50	[252,290]	[130,149]	[8.0, 9.2]
55	[333,381]	[149,170]	[8.7, 9.9]
60	[454,516]	[192,219]	[11.6, 13.1]
65	[551,634]	[298,343]	[14.2, 16.3]
70	[631,726]	[1238,1424]	[17.0, 19.6]
75	[757,871]	[1664,1915]	[20.2, 23.2]
80	[863,893]	[2070,2382]	[26.5, 28.7]
85	[963,990]	[2369,2725]	[29.8, 32.3]

Table 2
Resistance of all sensors with respect to change in relative humidity.

Relative Humidity %RH	Ag/MR/Ag Resistance MΩ	Al/TPPNi/Al Resistance MΩ	Ag/ Cu_2O-PEPC/Ag Resistance MΩ
15	[35,47]	[3009,4015]	[78,106]
20	[34,45]	[2674,3572]	[72,101]
25	[33,44]	[2305,3091]	[63,92]
30	[32,43]	[2237,2997]	[52,81]
35	[32,41]	[2131,2741]	[43,68]
40	[31,40]	[2010,2580]	[22,47]
45	[30,38]	[1770,2276]	[27, 33.8]
50	[29,38]	[1574,2129]	[22,30]
55	[28,35]	[1343,1636]	[15,21]
60	[27,34]	[1044,1250]	[9,13]
65	[27,32]	[713,837]	[5.3, 11.3]
70	[26,30]	[315,348]	[2.6, 5.1]
75	[27.3, 27.9]	[288,295]	[1.9, 3.7]
80	[25.6, 26.2]	[259,264]	[0.9, 1.7]
85	[21.5, 21.8]	[259,263]	[0.2, 0.9]

Table 3
Classical analysis of the capacitance of sensors.

Relative Humidity %RH	Ag/MR/Ag Capacitance pF	Al/TPPNi/Al Capacitance pF	Ag/ Cu_2O-PEPC/Ag Capacitance pF
15	78.6	85	1.1
20	85.7	91	1.3
25	107.1	97	2.9
30	135.7	99	3.0
35	171.4	107	4.0
40	192.9	114	5.0
45	235.7	137	5.6
50	271.4	140	8.6
55	357.1	160	9.3
60	485.7	206	12.4
65	592.9	321.3	15.2
70	678.6	1331.1	18.3
75	814.3	1790.2	21.7
80	928.6	2226.2	27.6
85	1035.7	2547.5	31.1

Table 4
Classical analysis of the capacitance of sensors.

Relative Humidity %RH	Ag/MR/Ag Resistance MΩ	Al/TPPNi/Al Resistance MΩ	Ag/ Cu_2O-PEPC/Ag Resistance MΩ
15	39.3	3512.3	92.5
20	39.0	3123.2	86.9
25	38.5	2698.0	77.7
30	38.0	2617.5	66.6
35	37.2	2436.2	56.4
40	35.8	2295.3	35.1
45	34.7	2023.5	21.3
50	33.8	1852.3	15.2
55	32.7	1489.9	11.3
60	31.9	1147.7	10.5
65	30.2	775.2	9.3
70	29.2	332.2	6.5
75	27.6	291.9	3.9
80	25.9	261.7	2.9
85	21.7	261.7	2.0

Tables 5 and 6 are expressing the neutrosophic analysis of the capacitance and resistance of sensors. From these tables, it is seen that neutrosophic analysis is a more reliable analysis as it uses indeterminacy and gives the whole information about the variance of capacitance and resistance at a specific value of the relative humidity. For example, at 15 %RH the classical value of the capacitance of Al/MR/Al is 78 pF (a single or fix-point value) i.e. $C_{(15\ \%RH)} = 78$ pF. But the other hand

Table 5
Neutrosophic analysis of the capacitance of sensors.

Relative Humidity %RH	Ag/MR/Ag Capacitance pF	Al/TPPNi/Al Capacitance pF	Ag/ Cu_2O-PEPC/Ag Capacitance pF
15	$74 + 82I_N$; $I_N\epsilon[0, 0.101]$	$80 + 89I_N$; $I_N\epsilon[0, 0.101]$	$0.9 + 1.1I_N$; $I_N\epsilon[0, 0.101]$
20	$81 + 90I_N$; $I_N\epsilon[0, 0.099]$	$86 + 95I_N$; $I_N\epsilon[0, 0.099]$	$1.1 + 1.2I_N$; $I_N\epsilon[0, 0.099]$
25	$100 + 113I_N$; $I_N\epsilon[0, 0.110]$	$91 + 102I_N$; $I_N\epsilon[0, 0.120]$	$2.7 + 3.0I_N$; $I_N\epsilon[0, 0.110]$
30	$127 + 144I_N$; $I_N\epsilon[0, 0.118]$	$92 + 105I_N$; $I_N\epsilon[0, 0.118]$	$2.8 + 3.2I_N$; $I_N\epsilon[0, 0.118]$
35	$160 + 182I_N$; $I_N\epsilon[0, 0.117]$	$100 + 113I_N$; $I_N\epsilon[0, 0.117]$	$3.8 + 4.2I_N$; $I_N\epsilon[0, 0.116]$
40	$181 + 204I_N$; $I_N\epsilon[0, 0.113]$	$107 + 120I_N$; $I_N\epsilon[0, 0.113]$	$4.7 + 5.3I_N$; $I_N\epsilon[0, 0.112]$
45	$220 + 250I_N$; $I_N\epsilon[0, 0.120]$	$128 + 145I_N$; $I_N\epsilon[0, 0.120]$	$5.3 + 6.0I_N$; $I_N\epsilon[0, 0.77]$
50	$252 + 290I_N$; $I_N\epsilon[0, 0.128]$	$130 + 149I_N$; $I_N\epsilon[0, 0.128]$	$8.0 + 9.2I_N$; $I_N\epsilon[0, 0.077]$
55	$333 + 381I_N$; $I_N\epsilon[0, 0.095]$	$149 + 170I_N$; $I_N\epsilon[0, 0.126]$	$8.7 + 9.9I_N$; $I_N\epsilon[0, 0.039]$
60	$454 + 516I_N$; $I_N\epsilon[0, 0.120]$	$192 + 219I_N$; $I_N\epsilon[0, 0.120]$	$11.6 + 13.1I_N$; $I_N\epsilon[0, 0.039]$
65	$551 + 634I_N$; $I_N\epsilon[0, 0.058]$	$298 + 343I_N$; $I_N\epsilon[0, 0.131]$	$14.2 + 16.3I_N$; $I_N\epsilon[0, 0.020]$
70	$631 + 726I_N$; $I_N\epsilon[0, 0.077]$	$1238 + 1424I_N$; $I_N\epsilon[0, 0.131]$	$17.0 + 19.6I_N$; $I_N\epsilon[0, 0.039]$
75	$757 + 871I_N$; $I_N\epsilon[0, 0.039]$	$1664 + 1915I_N$; $I_N\epsilon[0, 0.131]$	$20.2 + 23.2I_N$; $I_N\epsilon[0, 0.058]$
80	$863 + 893I_N$; $I_N\epsilon[0, 0.039]$	$2070 + 2382I_N$; $I_N\epsilon[0, 0.131]$	$26.5 + 28.7I_N$; $I_N\epsilon[0, 0.39]$
85	$963 + 990I_N$; $I_N\epsilon[0, 0.020]$	$2369 + 2725I_N$; $I_N\epsilon[0, 0.131]$	$29.8 + 32.3I_N$; $I_N\epsilon[0, 0.058]$

Table 6
Neutrosophic analysis of the resistance of sensors.

Relative Humidity %RH	Ag/MR/Ag Resistance MΩ	Al/TPPNi/Al Resistance MΩ	Ag/ Cu_2O-PEPC/Ag Resistance MΩ
15	$35 + 47I_N$; $I_N\epsilon[0, 0.251]$	$3009 + 4015I_N$; $I_N\epsilon[0, 0.251]$	$78 + 106I_N$; $I_N\epsilon[0, 0.286]$
20	$34 + 45I_N$; $I_N\epsilon[0, 0.251]$	$2674 + 3572I_N$; $I_N\epsilon[0, 0.251]$	$72 + 101I_N$; $I_N\epsilon[0, 0.284]$
25	$33 + 44I_N$; $I_N\epsilon[0, 0.254]$	$2305 + 3091I_N$; $I_N\epsilon[0,0.245]$	$63 + 92I_N$; $I_N\epsilon[0, 0.316]$
30	$32 + 43I_N$; $I_N\epsilon[0, 0.254]$	$2237 + 2997I_N$; $I_N\epsilon[0, 0.245]$	$52 + 81I_N$; $I_N\epsilon[0, 0.358]$
35	$32 + 41I_N$; $I_N\epsilon[0, 0.222]$	$2131 + 2741I_N$; $I_N\epsilon[0, 0.222]$	$43 + 68I_N$; $I_N\epsilon[0, 0.363]$
40	$31 + 40I_N$; $I_N\epsilon[0, 0.221]$	$2010 + 2580I_N$; $I_N\epsilon[0, 0.221]$	$22 + 47I_N$; $I_N\epsilon[0, 0.522]$
45	$30 + 38\ I_N$; $I_N\epsilon[0, 0.223]$	$1770 + 2276I_N$; $I_N\epsilon[0, 0.223]$	$27 + 33.8I_N$; $I_N\epsilon[0, 0.740]$
50	$29 + 38I_N$; $I_N\epsilon[0, 0.261]$	$1574 + 2129I_N$; $I_N\epsilon[0, 0.261]$	$22 + 30I_N$; $I_N\epsilon[0, 0.991]$
55	$28 + 35I_N$; $I_N\epsilon[0, 0.179]$	$1343 + 1636I_N$; $I_N\epsilon[0, 0.179]$	$15 + 21I_N$; $I_N\epsilon[0, 0.929]$
60	$27 + 34I_N$; $I_N\epsilon[0, 0.165]$	$1044 + 1250I_N$; $I_N\epsilon[0, 0.165]$	$9 + 13I_N$; $I_N\epsilon[0, 0.924]$
65	$27 + 32I_N$; $I_N\epsilon[0, 0.148]$	$713 + 837I_N$; $I_N\epsilon[0, 0.148]$	$5.3 + 11.3I_N$; $I_N\epsilon[0, 0.924]$
70	$26 + 30I_N$; $I_N\epsilon[0, 0.096]$	$315 + 348I_N$; $I_N\epsilon[0,n0.096]$	$2.6 + 5.1I_N$; $I_N\epsilon[0, 0.876]$
75	$27.3 + 27.9I_N$; $I_N\epsilon[0, 0.023]$	$288 + 295I_N$; $I_N\epsilon[0, 0.024]$	$1.9 + 3.7I_N$; $I_N\epsilon[0, 0.472]$
80	$25.6 + 26.2I_N$; $I_N\epsilon[0, 0.020]$	$259 + 264I_N$; $I_N\epsilon[0, 0.020]$	$0.9 + 1.7I_N$; $I_N\epsilon[0, 0.500]$
85	$21.5 + 21.8I_N$; $I_N\epsilon[0, 0.014]$	$259 + 263I_N$; $I_N\epsilon[0, 0.014]$	$0.2 + 0.9I_N$; $I_N\epsilon[0, 0.523]$

neutrosophic analysis gives an equation $C_{(15\ \%RH)} = 74 + 82I_N$ with the indeterminacy interval $I_N\epsilon[0, 0.098]$. According to neutrosophic analysis, the value of capacitance lies between 74 and 82 by put indeterminacy values.

4.2. *Graphical comparison of neutrosophic and classical analysis of capacitance and resistance of humidity sensors*

The graphical comparison of neutrosophic and classical analysis for capacitance and resistance of Ag/MR/Ag, Al/TPPNi/Al and Ag/Cu_2O-PEPC/Ag are shown in Figs. 3–5.

The above graphs are showing the comparison between classical and neutrosophic analysis. For capacitance the classical and neutrosophic graphs are looking about the same i.e. having a small plotting difference, this is because there is a small variance of capacitance as compared to the resistance (small variance gives a small interval of indeterminacy). On the other hand, there is a large difference between classical and neutrosophic graphs of resistance. Because there is a large variance of resistance (large variance gives a large interval of indeterminacy). One can easily see that classical graphs are less flexible and informative to explain the capacitance and resistance of sensors as these are drawn on fix-point values. But neutrosophic graphs are enough flexible and informative to explain and conclude the problem. Generally, it is seen that most researchers have used classical graphs in their works either in form of a single line plot or in the form of an error bar graph for expressing the data variation. But statistically, these are not effective plots as the error bar shows the error found in data, not variance. When a researcher uses an error bar it means that he is graphically expressing the data error (which may be due to personal error, sample handling error, or mechanic error) instead of data variance. But the neutrosophic approach is a remarkable approach to analysis the data analysis. That's why we have used the neutrosophic approach for the analysis of the variance of capacitance and resistance of humidity sensors with changes in relative humidity.

5. Concluding remarks

This study belongs to the material statistics as we have used the statistics to analyze the imprecise data of electric properties like capacitance and resistance belonging to humidity sensors based on different materials. For this purpose, we have used the neutrosophic method to analyze the capacitance and resistance of humidity sensors. Ag/MR/Ag, Al/TPPNi/Al and Ag/ Cu2O-PEPC/Ag humidity sensors are used in this work, whose data on capacitance and resistance has been collected from previously published papers with some assumptions (like data is intervals). We have applied classical as well as neutrosophic formulas to the collected data and drawn the graphs of the output. We have compared the methods as well as output graphs and found which is more reliable for the analysis of sensing data. As a result, it is observed that classical analysis is not effective in explaining the variation of capacitance and resistance with respect to change in relative humidity as data loss its indeterminacy. But the neutrosophic analysis is more effective. It is concluded that neutrosophic statistics is more effective, reliable and much informative in taking decisions as well as classical statistics.

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None.

CRediT authorship contribution statement

U.A and M.A wrote the paper. J.A edits the paper.

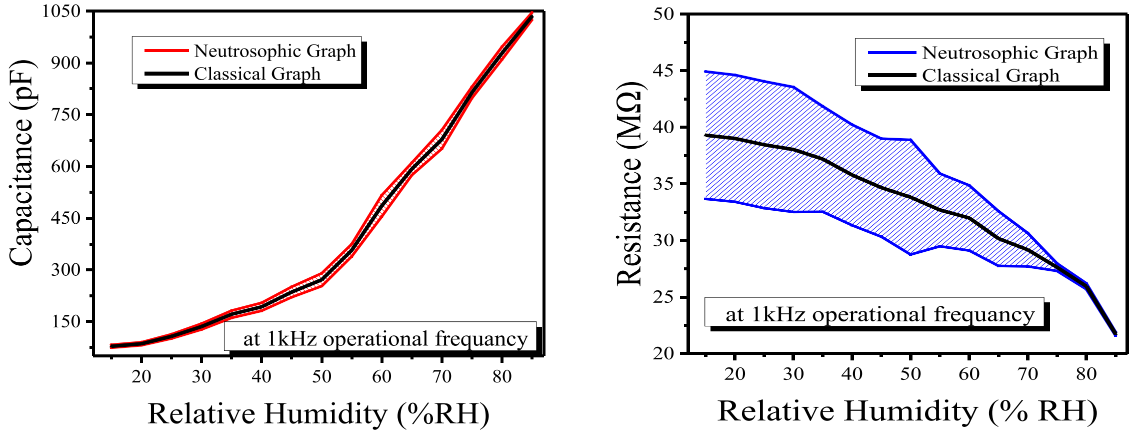

Fig. 3. Left side plot is capacitance and right side plot is resistance of Ag/MR/Ag.

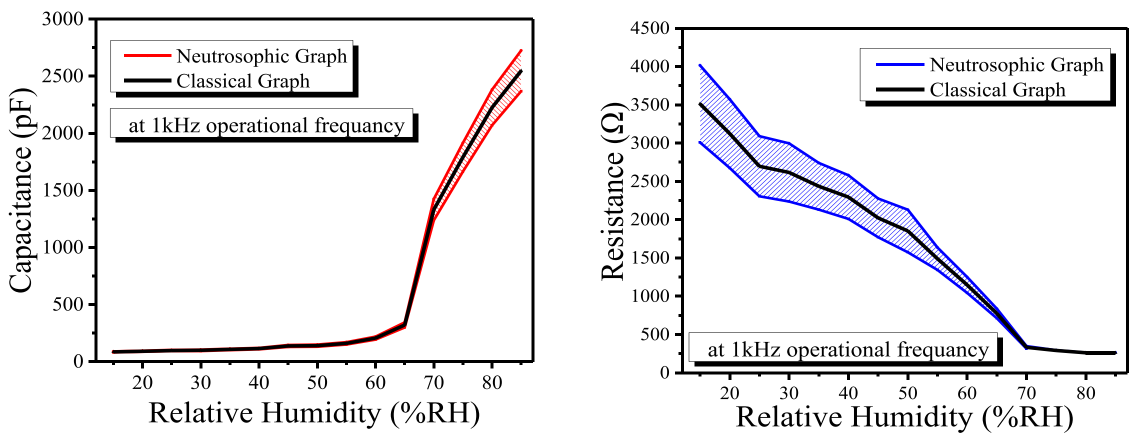

Fig. 4. Left side plot is capacitance and right side plot is resistance of Al/TPPNi/Al.

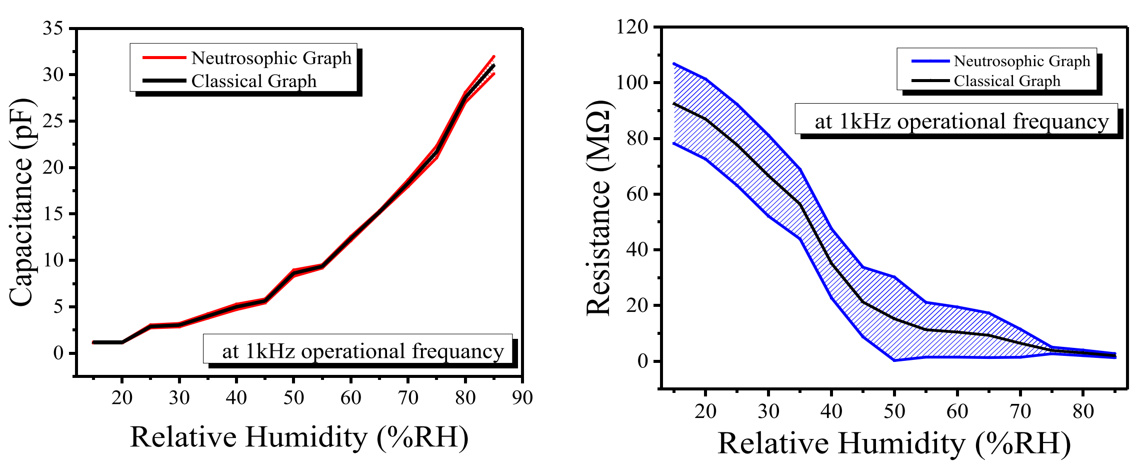

Fig. 5. Left side plot is capacitance and right side plot is resistance of Ag/ Cu2O-PEPC/Ag.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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