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Abstract: Carbon nano tubes (CNT) are the main parts of the electronic devices. Due to high carrier mobility, these devices have very high speed. CNT has a wide range of application in making sensors which can detect different types of diseases, materials, viruses and bacteria. The main problem in the CNT based field effect transistors (CNTFETs) is leakage current. For the reduction of leakage current, high k-gate dielectric are the most suitable materials. The purpose of this research is to find the most suitable high k-gate dielectric for the CNTFETs using Neutrosophic Hypersoft set TOPSIS (NHSS-TOPSIS). Since NHSS-TOPSIS are useful when attributes are more than one and are further bi-furcated. The concepts of TOPSIS has practical applications in computational intelligence, machine learning, image processing, neural networks, medical diagnosis, and decision analysis. A practical application for ranking of alternatives with newly developed NHSS-TOPSIS approach is illustrated by a numerical example for CNTFETs. The validity and superiority of NHSS-TOPSIS with existing approaches is also given with the help of a comparison analysis.

Keywords: Carbon Nano Tube (CNT), Neutrosophic Soft Set (NSS), Hypersoft Set, CNTFETs, K-Dielectrics, TOPSIS, Neutrosophic Hypersoft Set (NHSS), MCDM.

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1. Introduction

Carbon nano tubes (CNT) are long, thin cylinders of carbon. They can be considered as a sheet of graphite rolled into a cylinder. Since its discovery by Iijima in 1991, it has caught the attention of the researchers due to its remarkable structure, physical and chemical properties. CNT has high electron mobility and larger mean free path for carrier transport. The transistors whose structure is based on CNT have larger transconductance [1-5]. Most of the CNT based transistors are made of single walled CNTs. These single walled CNTs have one dimensional structure. Due to this, the carrier movement is limited to a single direction. So the scattering of charge carriers at different angles is prevented. Also, it causes the throw transfer of charge carriers [6-12].

The first CNT based transistor were constructed in 1998 after which a lot of research have been done to improve CNT based transistors. The switching in CNT based field effect transistors (CNTFET) may be arisen at contact or in bulk as compared to conventional bulk switched Si devices. Also, the switching process depends upon CNT diameter, nature of electrodes, geometry of electrodes, device geometry and gate dielectric [13-14]. CNTFETs have many advantages over Si based FETs. CNTFETs may operate in ballistic regime with high k-gate dielectrics which causes the transistor to work at higher speed. They are widely used for making sensors. These sensors are able to detect proteins, DNA sequence, bacteria and toxic materials [15-21].

The performance of CNTFETs is dependent upon source material, drain material and gate dielectric. With the advancement of the electronics, the size (dimension) of electronic devices is becoming smaller day by day. The decrease in size causes a leakage current. The main purpose of high k-gate dielectrics is to reduce leakage current. The high k-gate dielectric which have been used so far with CNTFETs are Hafnium Oxide (HfO_2), Aluminum Oxide (Al_2O_3), Hafnium Silicate ($HfSiO_4$), Zirconia (ZnO_2), Yttrium Oxide (Y_2O_3), Lanthanum Oxide (La_2O_3), Silicon dioxide (SiO_2) and Silicon Nitride (Si_3N_4) [22-31].

Zadeh [32] advanced his significant idea of fuzzy sets in 1965 to deal with various styles of uncertainties and proposed fuzzy sets and this theory was extended by [33] named as Intuitionistic fuzzy number theory. Smarandache [34] initiated the notion of neutrosophic sets which consider indeterminate/uncertain information in today's problems and incorporated not only membership and non-membership grades, but also indeterminacy grades assigned each component of the discourse universe with is limitation that the sum of three independent grades chosen in the interval [0,3]. Later on, fuzzy, intuitionist and neutrosophy theories were extended to fuzzy softset [35,36] intuitionistic soft set [37] and neutrosophic soft set [38]. Smarandache [39] generalized soft set to hyper soft set (HSS's) by changing the function into multi decision function. The HSS's was extended to neutrosophic hypersoft set (NHSS) [40] along with some MCDM techniques like TOPSIS and many applications [41-44]

In this research, eight different k-dielectrics are considered. The motivation of this research is to find which k-dielectric is most suitable alternate of CNTFETs for high power communication. The modelling of this problem shows that attributes are more than one, and are further bi-furcated. Thus, keeping in mind, the set structure of hypersoft sets we decided to apply NHSS-TOPSIS technique to find the optimal choice for k-dielectrics and results are compared with [45].

The remainder of this paper is structured as follows: Firstly, fundamental definitions are given about hypersoft set and neutrosophic hypersoft set theory. After, the step-wise algorithm of NHSS-TOPSIS is present. In section 3, we propose the idea of a case study of CNTFETs and some parameters have been considered. Section 4 provides the comparative analysis of calculation. Finally, in Section 5, a conclusion is outlined with future directions and limitations.

2.Preliminaries

Definition 2.1: Semiconductors [10]

These are the materials which are poorer conductors than metals but better than insulators. For example, Silicon (Si), Germanium (Ge) and Gallium Arsenide.

Definition 2.2: Transistors [6]

It is an electrical device which consist of two PN junctions fabricated on a same single crystal. It has three main parts i.e. emitter, base and collector. Transistors are used to amplify and switch the electronic signals and electrical power.

Definition 2.3: Dielectrics [30]

These are the materials which are poor conductors of electricity. It is an insulator but an effective supporter to electric filed.

Definition 2.4: High k Dielectrics Materials [31]

Dielectric materials which have high value of dielectric constant are called high k dielectric materials. Metal oxides have usually had high dielectric constant. They are usually used in MOSFETs as gate dielectric.

Definition 2.5: Carbon Nano Tube (CNT) [47]

These are tubes made of carbon with diameters typically measured in nanometers range. Carbon nanotube is theoretically distinct as a cylinder fabricated of rolled up grapheme sheet. Carbon nanotubes often refer to single-wall carbon nanotubes (SWCNTs). Single-wall carbon nanotubes are one of the allotropes of carbon, intermediate between fullerene cages and flat graphene. Most of the physical properties of carbon nanotubes derive from graphene.

Definition 2.6: Carbon Nano Tube Field Effective Transistors (CNTFETs) [48]

They are referred as a field-effect transistor in which a single carbon nanotube or an array of carbon nanotubes is used as the channel material instead of bulk silicon which is used in the traditional field-effect transistor. They were first discovered in 1998. CNTFET is a nano scale device that can provide low-power integrated circuits with high performance and high-power density.

Definition 2.7: Neutrosophic Hypersoft Set (NHSS) [39-40]

Let $\mathbb{U}$ be the universal set and $\mathbb{P}(\mathbb{U})$be the power set of $\mathbb{U}$. Consider $l^1, l^2, l^3 \dots l^n$ for $n \geq 1$, be n well-defined attributes, whose corresponding attributive values are respectively the set $L^1, L^2, L^3 \dots L^n$ with $L^i \cap L^j = \emptyset$, for $i \neq j$ and $i, j\epsilon\{1,2,3 \dots n\}$ and their relation $L^1 \times L^2 \times L^3 \dots L^n = \$$, then the pair $(₣, \$)$ is said to be Neutrosophic Hypersoft set (NHSS) over $\mathbb{U}$ where;

$₣: L^1 \times L^2 \times L^3 \dots L^n \rightarrow \mathbb{P}(\mathbb{U})$and

$₣(L^1 \times L^2 \times L^3 \dots L^n) = \{< x, T(₣(\$)), I(₣(\$)), F(₣(\$)) >, x \in \mathbb{U}\}$ where T is the membership value of truthiness, I is the membership value of indeterminacy and F is the membership value of falsity such that $T, I, F: \mathbb{U} \rightarrow [0,1]$ also $0 \leq T(₣(\$)) + I(₣(\$)) + F(₣(\$)) \leq 3$.

3. Calculations

In this section an algorithm is proposed to solve MCDM problem under neutrosophic environment.

3.1 Algorithm

TOPSIS (Technique for Order Preference by Similarly to Ideal Solution) is a suitable approach to deal with multi-attribute decision making problems.

Consider a multi-attribute decision making problem based on neutrosophic hypersoft sets (NHSSs) in which $\tilde{Ư} = \{\tilde{ư}^1, \tilde{ư}^2, \dots \tilde{ư}^a\}$ be the set of alternatives and $Ł_1, Ł_2, \dots Ł_b$ be the sets of attributes and their corresponding attributive values are respectively the set $Ł_1^a, Ł_2^b, \dots Ł_b^z$ where $a, b, c, \dots z = 1,2, \dots n$. Let $\hat{w}^j$ be the weight of attributes $Ł_j^z, j = 1,2 \dots b$, where $0 \leq \hat{w}^j \leq 1$ and

$\sum_{j=1}^{b} \hat{\text{w}}^{j} = 1$. Suppose that $\text{Đ} = (\text{Đ}_1, \text{Đ}_2, \dots \text{Đ}_t)$ be the set of t decision makers and Δ^x be the weight of t decision-makers with $0 \leq \Delta^x \leq 1$ and $\sum_{x=1}^{t} \Delta^x = 1$. Let $\left[A_{ij}^{x}\right]_{a\times b}$ be the decision matrix where $A_{ij}^{x} = \left(\text{Ţ}_{ijk}^{x}, \dot{\text{I}}_{ijk}^{x}, \dot{\text{F}}_{ijk}^{x}\right)$, $i = 1,2,3 \dots a\,, j = 1,2,3, \dots b, k = a, b, c, \dots z$ and $\text{Ţ}_{ijk}^{x}, \dot{\text{I}}_{ijk}^{x}, \dot{\text{F}}_{ijk}^{x} \in [0,1]$, $0 \leq \text{Ţ}_{ijk}^{x} + \dot{\text{I}}_{ijk}^{x} + \dot{\text{F}}_{ijk}^{x} \leq 3$. Utilizing the following steps, the determination strategy for the selection of alternatives can be obtained.

Step 1: Determine the Weight of Decision Makers

Let $\left[A_{ij}^{x}\right]_{a\times b}$ be the decision matrix where it is given as follows:

$$\left[A_{ij}^{x}\right]_{a\times b} = \begin{bmatrix} \text{Ţ}_{\text{Ļ}_1^a}^{x}(\text{ữ}_1), \dot{\text{I}}_{\text{Ļ}_1^a}^{x}(\text{ữ}), \dot{\text{F}}_{\text{Ļ}_1^a}^{x}(\text{ữ}_1)\ \text{Ţ}_{\text{Ļ}_2^b}^{x}(\text{ữ}_1), \dot{\text{I}}_{\text{Ļ}_2^b}^{x}(\text{ữ}_1), \dot{\text{F}}_{\text{Ļ}_2^b}^{x}(\text{ữ}_1) \cdots \text{Ţ}_{\text{Ļ}_b^z}^{x}(\text{ữ}), \dot{\text{I}}_{\text{Ļ}_b^z}^{x}(\text{ữ}), \dot{\text{F}}_{\text{Ļ}_b^z}^{x}(\text{ữ})\ \text{Ţ}_{\text{Ļ}_1^a}^{x}(\text{ữ}_2), \dot{\text{I}}_{\text{Ļ}_1^a}^{x}(\text{ữ}_2), \dot{\text{F}}_{\text{Ļ}_1^a}^{x}(\text{ữ}_2)\ \text{Ţ}_{\text{Ļ}_2^b}^{x}(\text{ữ}_2), \dot{\text{I}}_{\text{Ļ}_2^b}^{x}(\text{ữ}_2), \dot{\text{F}}_{\text{Ļ}_2^b}^{x}(\text{ữ}_2) \\ \cdots\ \text{Ţ}_{\text{Ļ}_b^z}^{x}(\text{ữ}_2), \dot{\text{I}}_{\text{Ļ}_b^z}^{x}(\text{ữ}_2), \dot{\text{F}}_{\text{Ļ}_b^z}^{x}(\text{ữ}_2)\ \vdots \vdots \ddots \vdots\ \text{Ţ}_{\text{Ļ}_1^a}^{x}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}_1^a}^{x}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}_1^a}^{x}(\text{ữ}_a)\ \text{Ţ}_{\text{Ļ}_2^b}^{x}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}_2^b}^{x}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}}^{x}(\text{ữ}_a) \cdots \text{Ţ}_{\text{Ļ}_b^z}^{x}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}_b^z}^{x}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}_b^z}^{x}(\text{ữ}_a) \end{bmatrix}$$

To find the ideal matrix, we average all the individual decision matrix $A_{ij}^{x}\ where\ x = 1,2 \dots t$ with the followings:

$$\left[A_{ij}^{\star`}\right]_{a\times b} =$$

$$\begin{bmatrix} \text{Ţ}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_1), \dot{\text{I}}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_1), \dot{\text{F}}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_1)\ \text{Ţ}_{\text{Ļ}_2^b}^{\star}(\text{ữ}_1), \dot{\text{I}}_{\text{Ļ}_2^b}^{\star}(\text{ữ}), \dot{\text{F}}_{\text{Ļ}_2^b}^{\star}(\text{ữ}_1) \cdots \text{Ţ}_{\text{Ļ}}^{\star}(u_1), \dot{\text{I}}_{\text{Ļ}_b^z}^{\star}(u_1), \dot{\text{F}}_{\text{Ļ}_b^z}^{\star}(u_1) \\ \text{Ţ}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_2), \dot{\text{I}}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_2), \dot{\text{F}}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_2)\ \text{Ţ}_{\text{Ļ}}^{\star}(\text{ữ}_2), \dot{\text{I}}_{\text{Ļ}_2^b}^{\star}(\text{ữ}_2), \dot{\text{F}}_{\text{Ļ}}^{\star}(\text{ữ}_2) \cdots \text{Ţ}_{\text{Ļ}_b^z}^{\star}(u_2), \dot{\text{I}}_{\text{Ļ}_b^z}^{\star}(u_2), \dot{\text{F}}_{\text{Ļ}_b^z}^{\star}(u_2) \\ \vdots \vdots \ddots \vdots \\ \text{Ţ}_{\text{Ļ}}^{\star}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}_1^a}^{\star}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}_1^a}^{\star}(u_a)\ \text{Ţ}_{\text{Ļ}_2^b}^{\star}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}}^{\star}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}_2^b}^{\star}(\text{ữ}_a) \cdots \text{Ţ}_{\text{Ļ}_b^z}^{\star}(\text{ữ}_a), \dot{\text{I}}_{\text{Ļ}_b^z}^{\star}(\text{ữ}_a), \dot{\text{F}}_{\text{Ļ}_b^z}^{\star}(\text{ữ}_a) \end{bmatrix}, \text{where}$$

$$A_{ij}^{\star} = \left(\text{Ţ}_{\text{Ļ}_j^k}^{\star}(\text{ữ}_i), \dot{\text{I}}_{\text{Ļ}_j^k}^{\star}(\text{ữ}), \dot{\text{F}}_{\text{Ļ}_j^k}^{\star}(\text{ữ}_i)\right)$$

$$= \left(1 - \prod_{x=1}^{t}\left(1 - \text{Ţ}_{\text{Ļ}_j^k}^{x}(\text{ữ})\right)^{\frac{1}{t}}, \prod_{x=1}^{t}\left(\dot{\text{I}}_{\text{Ļ}_j^k}^{x}(\text{ữ}_i)\right)^{\frac{1}{t}}, \prod_{x=1}^{t}\left(\dot{\text{F}}_{\text{Ļ}_j^k}^{x}(\text{ữ}_i)\right)^{\frac{1}{t}}\right)$$

Step 2: Determine the weight of attributes

the elements of A_{ij} in the matrix $\left[A_{ij}\right]_{a\times b}$ is calculated as $\left[A_{ij}\right]_{a\times b} = \left(1 - \prod_{x=1}^{t}\left(1 - \text{Ţ}_{\text{Ļ}_j^k}^{x}(\text{ữ}_i)\right)^{\Delta^x}, \prod_{x=1}^{t}\left(\dot{\text{I}}_{\text{Ļ}_j^k}^{x}(\text{ữ}_i)\right)^{\Delta^x}, \prod_{x=1}^{t}\left(\dot{\text{F}}_{\text{Ļ}_j^k}^{x}(\text{ữ}_i)\right)^{\Delta^x}\right)$, $i = 1,2,3 \dots a\,, j = 1,2,3, \dots b\ and\ x = 1,2, \dots t$.

Step 3: Determine the weight of attributes

In the decision-making procedure, decision-makers may perceive that all attributes are not similarly significant. In this manner, each decision-maker may have their own opinion regarding attribute weights. To acquire the gathering assessment of the picked attributes, all the decision-makers opinions for the importance of each attribute need to be aggregated. For this purpose, weight $\hat{\text{w}}^{j}$ of attributes $Ⱡ_j^z, j = 1,2 \dots b$ is calculated as $\hat{w}^j = \left(Ţ_{Ⱡ_j}, İ_{Ⱡ_j}, Ḟ_{Ⱡ_j}\right) = \left(1 - \prod_{x=1}^{t}\left(1 - Ţ_{Ⱡ_j}^{x}\right)^{\Delta^x}, \prod_{x=1}^{t}\left(İ_{Ⱡ_j}^{x}\right)^{\Delta^x}, \prod_{x=1}^{t}\left(Ḟ_{Ⱡ_j}^{x}\right)^{\Delta^x}\right)$.

Step 4: Calculate weighted aggregated decision matrix

After finding the weights of individual attributes, we use the weights to each row of the aggregated decision matrix with $\left[A_{ij}^{\omega}\right]_{a\times b} = \left(Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i), İ_{Ⱡ}^{\omega}(\tilde{ŭ}_i), Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right) = \left((Ţ_{Ⱡ_j^k}(\tilde{ŭ}_i).Ţ_{Ⱡ_j}), \left(İ_{Ⱡ_j^k}(\tilde{ŭ}_i) + İ_{Ⱡ_j} - İ_{Ⱡ_j^k}(\tilde{ŭ}_i).İ_{Ⱡ_j}\right), \left(Ḟ_{Ⱡ_j^k}(\tilde{ŭ}_i) + Ḟ_{Ⱡ_j} - Ḟ_{Ⱡ}(\tilde{ŭ}_i).Ḟ_{Ⱡ_j}\right)\right)$. Then, we get a weighted aggregated decision matrix.

Step 5: Determine the ideal solution

In real life we deal with two types of attributes, one is benefit type attributes and the other is cost type attributes. In our MAGDM problem, we also deal with these two types of attributes. Let C_1 be the benefit type attributes and C_2 be the cost type attributes. The neutrosophic hypersoft positive ideal solution is given as $A_j^{\omega^+} = \left(Ţ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i), İ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i), Ḟ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i)\right) = \{\left\{Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{İ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}\ , j \in C_1 \left\{Ţ_{Ⱡ}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{İ_{Ⱡ}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}\ , j \in C_2$. Similarly, the neutrosophic hypersoft negative ideal solution is given as $A_j^{\omega^-} = \left(Ţ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ}_i), İ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ}_i), Ḟ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ}_i)\right) = \{\left\{Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{İ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}\ , j \in C_1 \left\{Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{İ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}, \left\{Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i)\right\}\ , j \in C_2$

Step 6 Calculate the distances

Now, we should find the Normalized Hamming distance between the alternatives and positive ideal solution with $Đ^{i+}\left(A_{ij}^{\omega}, A_j^{\omega^+}\right) = \frac{1}{3b}\sum_{j=1}^{b} \left(\left|Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - Ţ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i)\right| + \left|İ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - İ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i)\right| + \left|Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - Ḟ_{Ⱡ_j^k}^{\omega^+}(\tilde{ŭ}_i)\right|\right)$. Similarly, we find the Normalized Hamming distance between the alternatives and positive ideal solution as $Đ^{i-}\left(A_{ij}^{\omega}, A_j^{\omega^-}\right) = \frac{1}{3b}\sum_{j=1}^{b} \{\left|Ţ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - Ţ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ}_i)\right| + \left|İ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - İ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ})\right| + \left|Ḟ_{Ⱡ_j^k}^{\omega}(\tilde{ŭ}_i) - Ḟ_{Ⱡ_j^k}^{\omega^-}(\tilde{ŭ}_i)\right|\}$.

Step 7 Calculate the relative closeness coefficient

Relative closeness index is used to rank the alternatives and it is calculated with, $i = 1, \dots, a$,

$$RC^i = \frac{Đ^{i-}\left(A_{ij}^{\omega}, A_j^{\omega^-}\right)}{max^i\left\{Đ^{i-}\left(A_{ij}^{\omega}, A_j^{\omega^-}\right)\right\}} - \frac{Đ^{i+}\left(A_{ij}^{\omega}, A_j^{\omega^+}\right)}{min^i\left\{Đ^{i+}\left(A_{ij}^{\omega}, A_j^{\omega^+}\right)\right\}}. \quad (11)$$

The set of selected alternatives are ranked according to the descending order of relative closeness index.

3.2 Numerical Example:

In this section, we will discuss the case study for the selection of high k-gate dielectric for CNTFETs using mathematical tools. CNTFETs are the main part of electronic devices these days. The problem of the leakage current affects its performance. The high k-gate dielectric can be used to reduce the problem of leakage current. So, the more efficient CNTFETs devices can be constructed alternatives are considered in Table 1.

SR NO.	DIELECTRIC MATERIAL	DIELECTRIC CONSTANT (k)	Band Gap $E_g\ (eV)$	Conduction band with respect to Si $\Delta E_c\ (eV)$	Structure
1	SiO_2	3.9	8.9	3.2	Amorphous
2	Al_2O_3	9.0	8.7	2.8	Amorphous
3	$HfSiO_4$	11	6.5	1.8	Tetra
4	ZrO_2	25	5.8	1.4	Mono, Tetra, Cubic
5	La_2O_3	30	6.0	2.3	Cubic
6	Y_2O_3	15	5.6	2.3	Cubic
7	HfO_2	25	5.7	1.4	Mono, Tetra, Cubic
8	Si_3N_4	7.0	5.1	2.4	Amorphous

TABLE 1: The alternatives with attributive values

Let U be the set of all dielectric materials that can be used at junction interface as gate dielectric, so U= {$Đ_1$, $Đ_2$, $Đ_3$, $Đ_4$, $Đ_5$, $Đ_6$, $Đ_7$, $Đ_8$}

Where $Đ_1 = SiO_2$, $Đ_2 = Al_2O_3$, $Đ_3 = HfSiO_4$, $Đ_4 = ZrO_2$, $Đ_5 = La_2O_3$, $Đ_6 = Y_2O_3$, $Đ_7 = HfO_2$, $Đ_8 = Si_3N_4$

Let us consider the following attributes;

$A_1 =$ Dielectric constant

$A_2 =$ Band Gap $E_g\ (eV)$

$A_3 =$ Conduction band with respect to Si $\Delta E_c\ (eV)$ $A_4 =$ Structure

So $Đ_i$ = Universal set of dielectrics where (i = 1, 2, 3, 4, 5, 6, 7, 8) and A_i = Set of attributes where (i = 1, 2, 3, 4).

$A_1^a = \ Dielectric\ constant = \{3.9, 9.0, 11, 25, 30, 15, 25, 7\}$

$A_2^b = \ Band\ Gap\ E_g\ (eV) = \{8.9, 8.7, 6.5, 5.8, 6.0, 5.6, 5.7, 5.1\}$

$A_3^c = \ Conduction\ band\ with\ respect\ to\ Si\ \Delta E_c\ (eV) = \{3.2, 2.8, 1.8, 1.4, 2.3, 2.3, 1.4, 2.4\}$

$A_4^d = \ Structure$

$= \{amorphous, amorphous, tetra, (cubic, mono, tetra), cubic, cubic, (cubic, mono, tetra), amorphous\}$

Now, let us define the relation for the function $f : Đ_1 \times Đ_2 \times Đ_3 \times Đ_4 \times Đ_5 \times Đ_6 \times Đ_7 \times Đ_8 \rightarrow P(\mathrm{U})$ as, $f(Đ_1 \times Đ_2 \times Đ_3 \times Đ_4 \times Đ_5 \times Đ_6 \times Đ_7 \times Đ_8) = (ɞ = dielectric\ constatn = 30, ʻΥ = Band\ gap = 8.9, \psi = Conduction = 2.3, \dot{ŋ} = structure = cubic) = (Đ_4 \times Đ_5 \times Đ_7)$ is the actual sample of the CNT for the CNTFETs. Three patients $\{Đ_4, Đ_5, Đ_7\}$ are selected based on sample. The panel of three doctors (decision-maker) $\{M^1, M^2, M^3\}$ will examine the sample and select the most relevant CNTFETs. These decision-makers give their valuable opinion in the form of neutrosophic number based on their experience and knowledge, and are presented in NHSM, separately, as follows:

$$[M^1]_{3\times4} = \begin{bmatrix} (ɞ(0.6,0.5,0.4)) & (ʻΥ(0.2,0.4,0.6)) & (\psi(0.2,0.3,0.2)) & (\dot{ŋ}(0.8,0.2,0.2)) \\ (ɞ(0.4,0.2,0.2)) & (ʻΥ(1.2,0.4,0.3)) & (\psi(1.0,0.7,0.8)) & (\dot{ŋ}(0.2,0.4,0.7)) \\ (ɞ(0.7,0.6,0.5)) & (ʻΥ(0.6,0.7,0.19)) & (\psi(0.5,0.4,0.31)) & (\dot{ŋ}(0.8,0.21,0.48)) \end{bmatrix}$$

$$[M^2]_{3\times4} = \begin{bmatrix} (ɞ(0.1,0.5,0.3)) & (ʻΥ(0.7,0.5,0.4)) & (\psi(0.8,0.3,0.7)) & (\dot{ŋ}(0.6,0.4,0.7)) \\ (ɞ(0.2,0.4,0.9)) & (ʻΥ(0.3,0.210.0)) & (\psi(1.0,0.1,0.9)) & (\dot{ŋ}(0.4,0.1,0.6)) \\ (ɞ(0.6,0.5,0.9)) & (ʻΥ(0.4,0.7,0.91)) & (\psi(0.3,0.6,0.41)) & (\dot{ŋ}(0.34,0.16,0.19)) \end{bmatrix}$$

$$[M^3]_{3\times4} = \begin{bmatrix} (ɞ(0.8,0.2,0.1)) & (ʻΥ(0.6,0.4,0.2)) & (\psi(0.6,0.3,0.5)) & (\dot{ŋ}(1.0,0.4,0.5)) \\ (ɞ(0.4,0.2,0.4)) & (ʻΥ(3.3,014,0.13)) & (\psi(0.12,0.2,0.44)) & (\dot{ŋ}(0.53,0.25,0.4)) \\ (ɞ(0.5,0.4,0.6)) & (ʻΥ(0.5,0.6,0.91)) & (\psi(0.3,05.,0.23)) & (\dot{ŋ}(0.8,0.1,0.3)) \end{bmatrix}$$

Step 1 Determine the Weights of Decision Makers

To determine the weights of the decision-makers, first, we find the similarity measure between each decision matrix $\{M^1, M^2, M^3\}$ and the ideal matrix $S^\star$ using $S(A_{ij}^x, A_{ij}^\star) = 1 - \frac{1}{3ab}\sum_i^a \sum_j^b \{\left|Ţ_{Ļ_j^k}^x(\tilde{ɥ}_i) - Ţ_{Ļ_j^k}^\star(\tilde{ɥ}_i)\right| + \left|\dot{I}_{Ļ_j^k}^x(\tilde{ɥ}_i) - \dot{I}_{Ļ_j^k}^\star(\tilde{ɥ}_i)\right| + \left|\dot{F}_{Ļ_j^k}^x(\tilde{ɥ}_i) - \dot{F}_{Ļ_j^k}^\star(\tilde{ɥ}_i)\right|\}$. So, $S\ (p_1, p_*) = 0.5641$, $S(p_1, p_*) = 0.1224$, $S(p_1, p_*) = 0.1046$. Now we calculate the weight $\Delta^x\ for\ (x = 1,2,3)$ of each decision-makers using $\Delta^x = \frac{S(A_{ij}^x, A_{ij}^*)}{\sum_{x=1}^t S(A_{ij}^x, A_{ij}^*)}$. We have

$$\Delta^1 = \frac{0.5641}{(0.5641 + 0.1224 + 0.1046)} = 0.7130$$

$$\Delta^2 = \frac{0.1224}{(0.5641 + 0.1224 + 0.1046)} = 0.1547$$

$$\Delta^3 = \frac{0.1046}{(0.5641 + 0.1224 + 0.1046)} = 0.1322$$

Step 2 Aggregate Neutrosophic Hypersoft Decision Matrices

Now we construct an aggregated neutrosophic hypersoft decision matrix NHSM, to obtain group decision. We obtain, $[p]_{3\times 4}$ =

$$\begin{bmatrix} \left(\beta(0.116, 0.341, 0.312)\right) \left(\Upsilon(0.896. 0.341, 0.334)\right) \left(\psi(0.234, 0.241, 0.210)\right) \left(\acute{\eta}(0.352, 0.112, 0.007)\right) \\ \left(\beta(0.621, 0.241, 0653)\right) \left(\Upsilon(0.342, 0.121, 0.732)\right) \left(\psi(0.234, 0.466, 0.369)\right) \left(\acute{\eta}(0.251, 0.144, 0.330)\right) \\ \left(\beta(0.871, 0.636, 0.346)\right) \left(\Upsilon(0.212, 0.1111, 0.203)\right) \left(\psi(0.223, 0.761, 0.474)\right) \left(\acute{\eta}(0.467, 0.831, 0.120)\right) \end{bmatrix}$$

Step 3 Determine the weight of attributes

Weight $\hat{w}^j$ of attributes $L_j, j = 1,2 \ldots b$ is calculated using $\hat{w}^j = \left(T_{L_j}, \dot{I}_{L_j}, \dot{F}_{L_j}\right) = \left(1 - \prod_{x=1}^{t} \left(1 - T_{L_j}^{x}\right)^{\Delta^x}, \prod_{x=1}^{t} \left(\dot{I}_{L_j}^{x}\right)^{\Delta^x}, \prod_{x=1}^{t} \left(\dot{F}_{L_j}^{x}\right)^{\Delta^x}\right)$.

we get $\hat{w}^1 = (0.7224, 0.6938, 0.2346), \hat{w}^2 = (0.6755, 0.1340, 0.1004), \hat{w}^3 = (0.2821, 0.1269, 0.0992)$

Step 4 Calculate the weighted aggregated decision matrix

After finding the weights of attributes, we apply these weights to each row of aggregated decision matrix using $\left[A_{ij}^{\omega}\right]_{a\times b} = \left(T_{L_j^k}^{\omega}(\tilde{u}_i), \dot{I}_{L_j^k}^{\omega}(\tilde{u}_i), \dot{F}_{L_j^k}^{\omega}(\tilde{u}_i)\right) = \left((T_{L_j^k}(\tilde{u}_i). T_{L_j}), \left(\dot{I}_{L_j^k}(\tilde{u}_i) + \dot{I}_{L_j} - \dot{I}_{L_j^k}(\tilde{u}_i). \dot{I}_{L_j}\right), \left(\dot{F}_{L_j^k}(\tilde{u}_i) + \dot{F}_{L_j} - \dot{F}_{L_j^k}(\tilde{u}_i). \dot{F}_{L_j}\right)\right)$. We get a weighted aggregated decision matrix $[S^{\omega}]$ as follows: $[S^{\omega}]_{3\times 4}$ =

$\left[\left(\beta(0.342, 0.121, 0.732)\right) \left(\Upsilon(0.754, 0.466, 0.369)\right) \left(\psi(0.871, 0.636, 0.346)\right) \left(\acute{\eta}(0.812, 0.1111, 0.203)\right) \left(\beta(0.467, 0.8\right.\right.$

Step 5: Determine the ideal solution

Neutrosophic hypersoft positive ideal solution is calculated using $S^{\omega^+} = [\left(\beta, (0.23,0.53,013)\right) \left(\Upsilon, (0.95, 0.16, 0.62)\right) \left(\psi, (0.75, 0.85, 0.75)\right) \left(\acute{\eta}, (0.42,0.85,0.13)\right)]$. Similarly, the neutrosophic hypersoft negative ideal solution is given as $S^{\omega^-} = [\left(\beta, (0.34, 0.52, 0.77)\right) \left(\Upsilon, (0.23, 0.32, 0.21)\right) \left(\psi, (0.86, 0.23, 0.11)\right) \left(\acute{\eta}, (0.12,0.09,0.03)\right)]$.

Step 6 Calculate the distance measure

Now we find the normalized hamming distance between the alternatives and positive ideal solution using $Ð^{i+}(A_{ij}^{\omega}, A_j^{\omega^+}) = \frac{1}{3b}\sum_{j=1}^{b} \left(\left|Ţ_{Ḽ_j^k}^{\omega}(\tilde{ư}_i) - Ţ_{Ḽ_j^k}^{\omega^+}(\tilde{ư}_i)\right| + \left|İ_{Ḽ_j^k}^{\omega}(\tilde{ư}_i) - İ_{Ḽ_j^k}^{\omega^+}(\tilde{ư}_i)\right| + \left|Ḟ_{Ḽ_j^k}^{\omega}(\tilde{ư}) - Ḟ_{Ḽ_j^k}^{\omega^+}(\tilde{ư})\right|\right)$. We get $Ð^{1+}(S_1^{\omega}, S^{\omega^+}) = 0.342$, $Ð^{2+}(S_2^{\omega}, S^{\omega^+}) = 0.127$, $Ð^{3+}(S_3^{\omega}, S^{\omega^+}) = 0.985$.

Similarly, we will find the normalized hamming distance between the alternatives and negative ideal solution using

$$Ð^{i-}(A_{ij}^{\omega}, A_j^{\omega^-}) = \frac{1}{3b}\sum_{j=1}^{b} \left(\left|Ţ_{Ḽ_j^k}^{\omega}(\tilde{ư}_i) - Ţ_{Ḽ_j^k}^{\omega^-}(\tilde{ư}_i)\right| + \left|İ_{Ḽ_j^k}^{\omega}(\tilde{ư}_i) - İ_{Ḽ_j^k}^{\omega^-}(\tilde{ư}_i)\right| + \left|Ḟ_{Ḽ_j^k}^{\omega}(\tilde{ư}_i) - Ḟ_{Ḽ_j^k}^{\omega^-}(\tilde{ư})\right|\right).$$

We get, $Ð^{1-}(S_1^{\omega}, S^{\omega^-}) = 0.741$, $Ð^{2-}(S_2^{\omega}, S^{\omega^-}) = 0.443$, $Ð^{3-}(S_3^{\omega}, S^{\omega^-}) = 0.332$.

Step 7: Calculate the relative closeness coefficient

Now we will calculate the relative closeness index using $Rp_i = \frac{Ð^{i-}(A_{ij}^{\omega}, A_j^{\omega^-})}{max^i\{Ð^{i-}(A_{ij}^{\omega}, A_j^{\omega^-})\}} - \frac{Ð^{i+}(A_{ij}^{\omega}, A_j^{\omega^+})}{min^i\{Ð^{i+}(A_{ij}^{\omega}, A_j^{\omega^+})\}}$.

We get

$$Rp_1 = \frac{0.4351}{0.4351} - \frac{0.332}{0.345} = -22.40$$

$$Rp_2 = \frac{0.443}{0.4351} - \frac{0.747}{0.345} = -32.50$$

$$Rp_3 = \frac{0.332}{0.4351} - \frac{0.345}{0.345} = -12.50$$

By using NHSS-TOPSIS for neutrosophic hypersoft sets, we can decide that which CNT is good for CNTFETs using the values of relative closeness coefficient in descending order. We rank the selected alternatives as shown in Table. 2 according to the descending order of relative closeness index as $Ð_5 > Ð_4 > Ð_7$. This shows that $Ð_5$ is the alternative which is goof for CNTFETs.

Alternative	$Ð_4$	$Ð_5$	$Ð_7$
Relatives Closeness using NHSS-TOPSIS	-22.40	-32.50	-12.50

Table 2. Relative closeness coefficient measurement and ranking of alternatives

4. Result Discussion

The performance of the CNTFET devices is primarily dependent on gate dielectric, source and drain material. The reduction of size of an electronic device causes leakage current which may be reduced by using high k gate dielectric as gate. The choice of this high k-gate dielectric depends on the properties of materials like dielectric constant, energy band gap etc. La_2O_3 is the best among all the potential candidates as gate dielectric as it has high dielectric constant as compared to all others. The drain current in CNTFET's increases with the relative dielectric constant for a fixed value of the drain voltage. So La_2O_3 gives the highest value of the drain current among all the other candidates for the gate dielectric. Moreover. La_2O_3 has high current on/off ratio and low leakage power which makes it a suitable candidate for CNT based electronic devices [45]. Difference between thermal expansion coefficient of CNT and thermal expansion coefficient of La_2O_3 is very small as compared to difference of other dielectrics [46] and present in Table 3.

Methods	Ranking of alternatives	Best alternatives
Ankita Dixit, Navneet Gupta. [45]	$Đ_5 > Đ_4 > Đ_7$.	$Đ_5$
Ankita Dixit, Navneet Gupta [46]	$Đ_4 > Đ_5 > Đ_7$.	$Đ_5$
The NHSS-TOPSIS	$Đ_5 > Đ_4 > Đ_7$.	$Đ_5$

TABLE 3. Comparison analysis of final ranking with existing methods

5. Conclusions

The concept of neutrosophic hypersoft TOPSIS (NHSS-TOPSIS) is a strong model for MADM. With the development of this technique we robust MADM method for CNTFETs selection by using NHSS-TOPSIS for NHSSs. Meanwhile, a practical application for ranking of alternatives with newly developed MADM approach is illustrated by a numerical example. We computed correlation coefficient and relative closeness by using our method and compared the results with existing methods of [45-46]. The validity and superiority of this method with existing approaches is also given with the help of a comparison analysis. Finally, it is deduced that NHSS-TOPSIS is more efficient, impressive and suitable.

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Conflicts of Interest

The authors declare no conflict of interest.

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