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# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 7 **Issue:** VIII **Month of publication:** August 2019

**DOI:**

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177*
*Volume 7 Issue VIII, Aug 2019- Available at www.ijraset.com*

# Designed and Analyzing of Electrochemical Therapy (EChT) Ablation and Dose-Planning

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***Abstract:*** ***Electrochemical therapy (EChT) is an ablation technique, tumors implies that diseased tissue is treated with direct current through the use of metallic electrodes inserted in the tumor, Electrolysis by direct electric current changes pH of environment which results in biological effect, It should be stressed that chlorine production also leads to lowered pH through the hydrolysis of chlorine. One effect of low pH is the permanent destruction of hemoglobin in the tissue, which results in destruction of tumor tissue When a cancer patient is not suitable for surgical operation and/or radio-_chemotherapy are not effective, EChT may show its special effectiveness.***
***Keywords: Liver cancer, Dose-Planning, Dielectric probe. EChT.***

## I. INTRODUCTION

Electrochemical therapy (EChT) is an ablation technique possessing advantage over other techniques due to no drugs usage, minimal invasive and minimal side effects. In EChT, continuous direct electric current is applied through two or more electrodes inserted locally in the tumor or in its close vicinity, with the objective to produce chemical changes in tumors [4]. Specifically, electrochemical treatment of tumors uses electrolysis to create acidic and alkaline zones around anodic and cathodic implant electrodes that contribute to tissue necrosis. Inserting electrodes (special produced by platinum) into tumor and connecting its with EChT apparatus, direct electric current arouse strong chemical reactions around electrodes and lead degeneration and necrosis of tumor cells. It is a new type method to treat tumor without surgical resection. The final result is caused by direct electric current inducing chemical reactions, so it is called EChT.

The electrochemical treatment of tumors implies that diseased tissue is treated with direct current through the use of metallic electrodes inserted in the tumor. When tissue is electrolyzed, two competing reactions take place at the anode: oxygen evolution and chlorine production. The oxygen-evolution reaction also produces H+ ions, which lower the pH close to the anode. It should be stressed that chlorine production also leads to lowered pH through the hydrolysis of chlorine. One effect of low pH is the permanent destruction of hemoglobin in the tissue, which results in destruction of tumor tissue.

$$2Cl^- = Cl_2(g) + 2e^-$$

$$2H_2O = 4H^+ + O_2(g) + 4e^-$$

One challenge in developing this method of cancer treatment is in predicting the doses required for tumor destruction. One possible tool for dose planning is by modeling the reactions that take place close to the electrodes.A first simple model for the development of dose-planning methods. More advanced models for dose planning, including secondary effects of chlorine, are analyzed in this paper.

## II. MODEL DEFINITION

This design uses the Tertiary Current Distribution, Nernst-Planck interface to predict the transport and reaction in the electrolysis of tumor tissue in a liver.

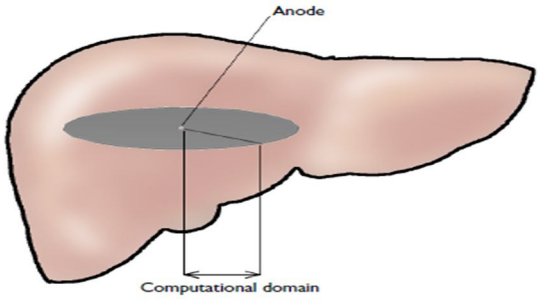


Figure 1: Anode inside Tumor.

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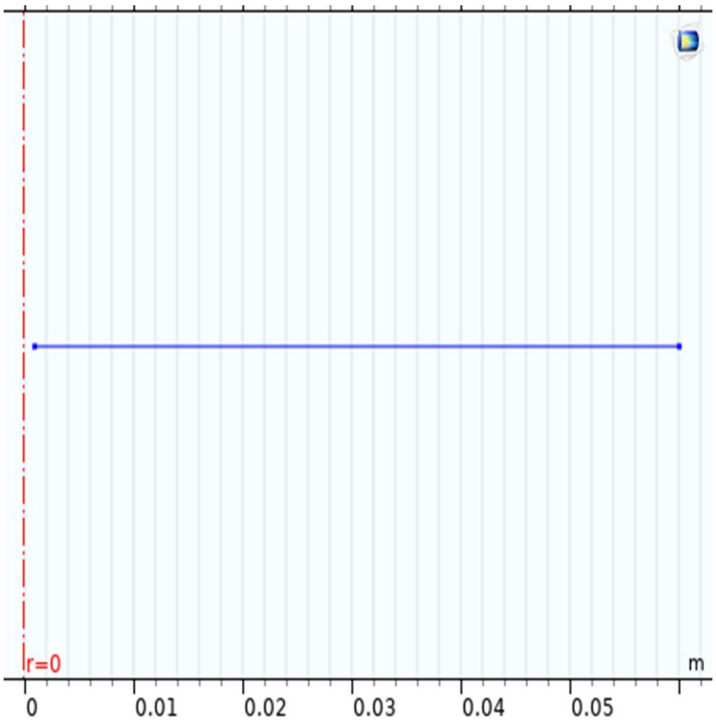


Figure 2: Anode Design.

A needle electrode is placed in the tumor, and transport is assumed to take place radially to and from this electrode. Because you can assume rotational symmetry, the computational domain reduces to a line. This simplified model considers only a 1D model of the transport between two points, that is, between the two electrodes.

Table 1: Parameters

| PARAMETERS | | |
|---|---|---|
| Name | Expression/Value | Description |
| r_a | 1[mm] | Anode radius |
| D_Na | 1.33e-9[m^2/s] | Diffusivity, Na |
| D_H | 9.31e-9[m^2/s] | Diffusivity, H |
| D_Cl | 2.03e-9[m^2/s] | Diffusivity, Cl |
| T | 298[K] | Temperature |
| Na0 | 0.16[mol/liter] | Initial concentration, Na |
| H0 | 1e-7[mol/liter] | Initial concentration, H |
| Cl0 | 0.16[mol/liter] | Initial concentration, Cl |
| z_Na | 1[1] | Charge number, Na |
| z_H | 1[1] | Charge number, H |
| z_Cl | -1[1] | Charge number, Cl |
| j_tot0 | 100[A/m^2] | Initial total current density |
| j_I0 | 1e-6[A/m^2] | Exchange current density |
| j_II0 | 10[A/m^2] | Exchange current density |
| V_ra0 | -1.4787[V] | Initial anode potential |
| E_eqI | 1.23[V] | Equilibrium potential, reaction I |
| E_eqII | 1.36[V] | Equilibrium potential, reaction II |
| r_ext | 60[mm] | Exterior boundary radius |

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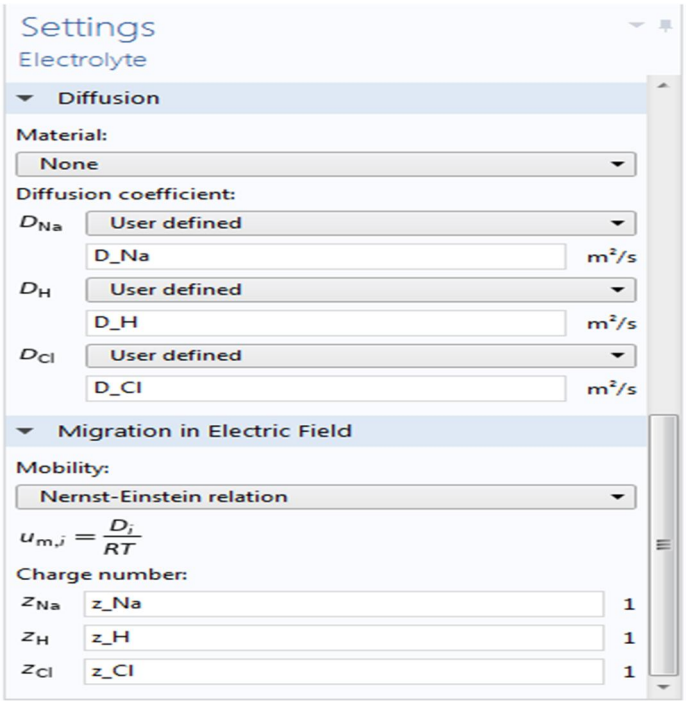
## III. RESULTS

The mobility, $u_{mi}$, can be expressed in terms of $D_i$, $R$, and $T$ as

$$u_{mi} = \frac{D_i}{RT}$$

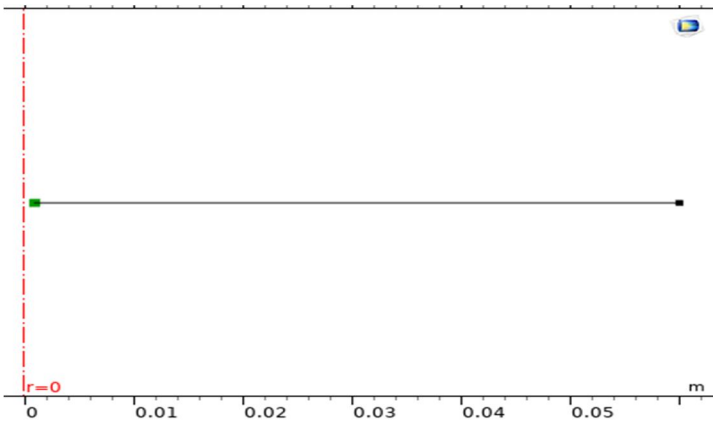
The electrolyte setting is shown in figure 3, with Diffusion coefficient of Na, H and Cl with values as described in table 1 i.e. 1.33 $nm^2/s$, 9.3 $nm^2/s$ and 2.03 $nm^2/s$ respectively with valency of 1,1 and -1 of Na, H and Cl.

Figure 3: Setting for Electrolyte




Flux describes any effect that appears to pass or travel (whether it actually moves or not) through a surface or substance.
At the electrode surface ($r = ra$) you use the Electrode Surface boundary node to specify the electrode reactions and the resulting fluxes for the ionic species that are included in the electrode reactions, H+ and Cl-. For the inert ionic species, Na+, the transport through the electrode surface equals zero. The expressions for molar fluxes at the boundary are based on the electrode reaction.

Figure 4: Domain 1 Anode




An electrode is an ideal catalyst in that the potential difference at the electrode-solution interface controls both the thermodynamics and the kinetics of the electrochemical reactions. However, the kinetics of electrode processes are relatively unselective. As shown in figure 5.

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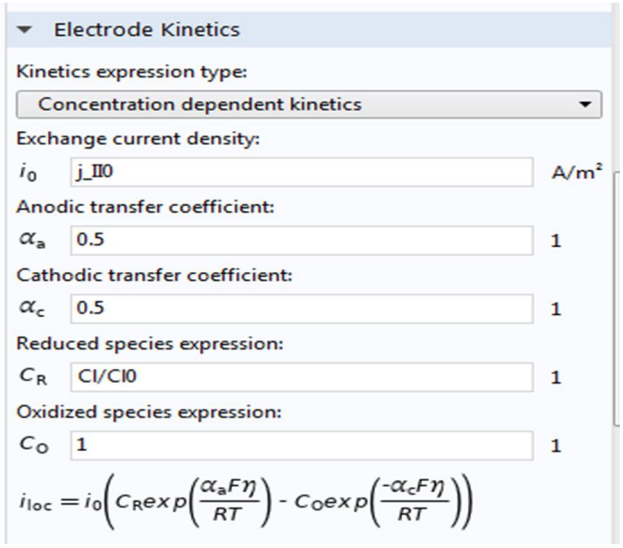
Figure 5: Electrode Kinetics




Initial total current density, exchange current density in reaction 1 and 2 are 100, $1*10^{-6}$, $1*10^{-6}$ A/m$^2$ respectively.
Stoichiometric coefficient ($v$) is the number appearing before the symbol for each compound in the equation for a chemical reaction. By convention, it is negative for reactants and positive for products. Stoichiometric coefficient for 1 electron transfer for anode equation is given in figure 6.

Figure 6: Stoichiometric coefficient

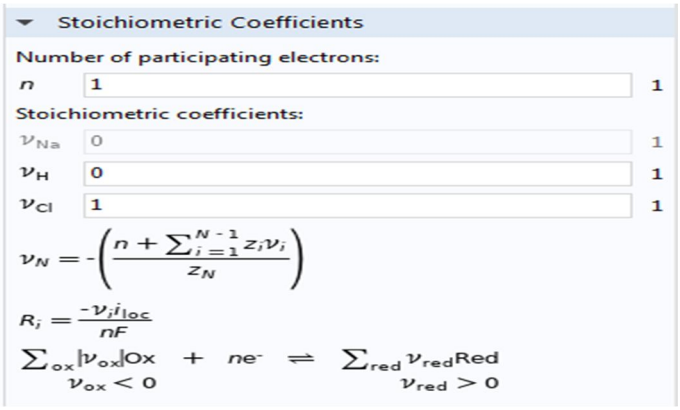
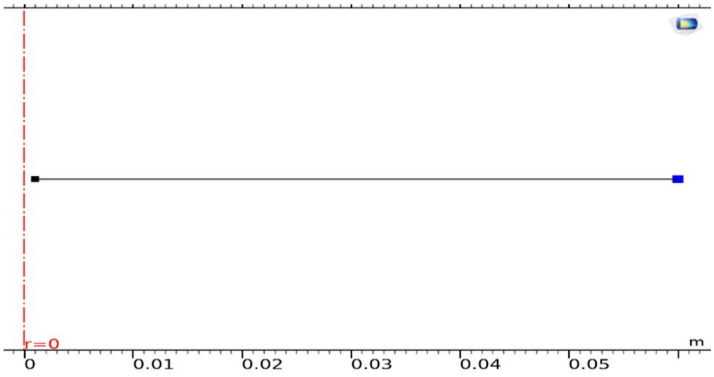



Figure 7: Anode domain 2




Initial anode potential, Equilibrium potential, reaction I and II with value of -1.4, 1.23 and 1.36V applied on domain 2 of anode receptively.

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## IV. RESULT

The electrolyte potential changes -1.45V initial to -2.1V with change in time 4200s.

Figure 8: Electrolyte Potential

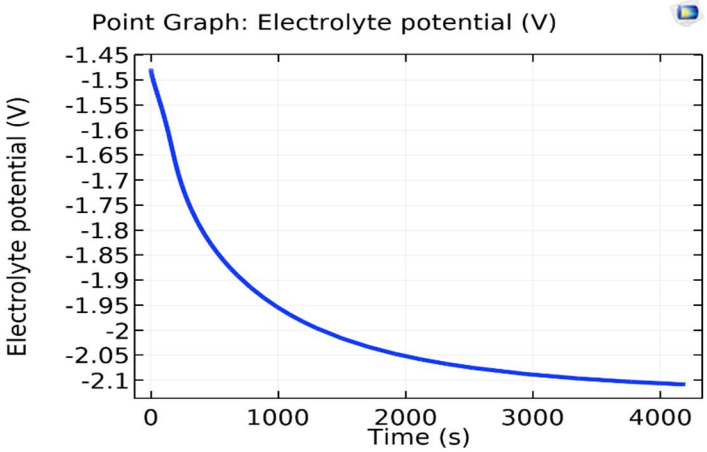



Figure 9: H Concentration

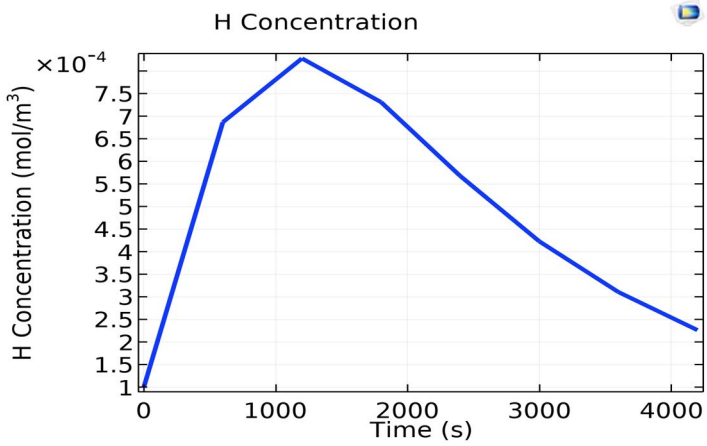
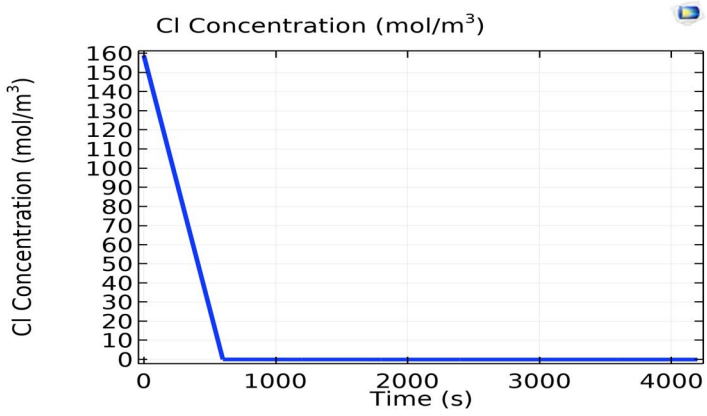



Figure 9 shows the H concentration as time increases the Hion concentration increases till 1200s then it decreases. The Cl concentration decreases with time. The corresponding plot for chloride (Figure 10) shows a continuous decrease of chloride concentration close to the anode surface. This in turn decreases the production of chlorine and increases oxygen evolution.

Figure 10: Cl Concentration

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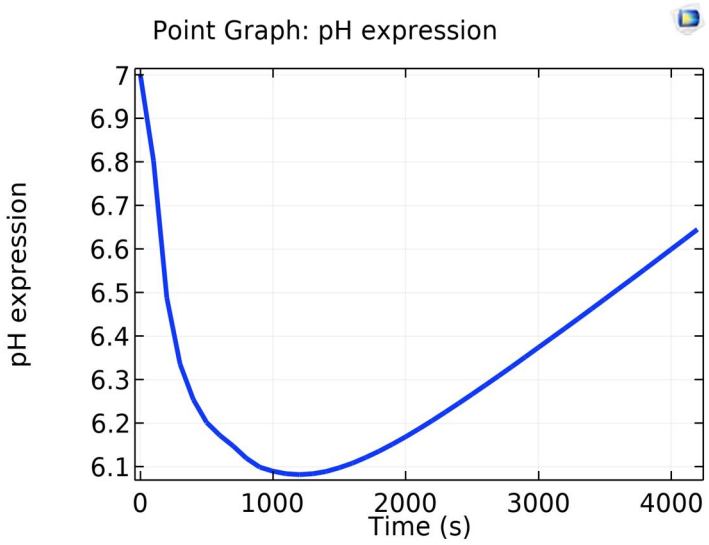
The pH value decreases with increase in time pH value goes 6.1 around 1000s shown in figure 11.

Figure 11: pH Value




The current-density plot in Figure 11 shows that the total current decreases rapidly as the concentration overvoltage for chlorine formation increases, due to lowered chloride concentration at the anode surface. The potential is then increased, which results in an increase in total current through increased oxygen evolution, shown in figure 12

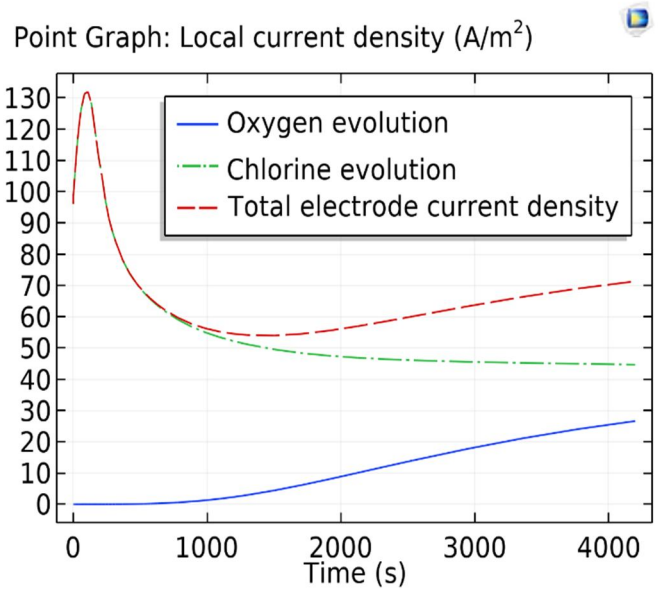



Figure 12: Oxygen evolution is the lowest graph

## V. CONCLUSION

One challenge in developing ablation using EChT treatment is in predicting the doses required for tumor destruction. One possible tool for dose planning is by modeling the reactions that take place close to the electrodes. This simplified model considers only a 1D model of the transport between two points, that is, between the two electrodes. The electrolyte potential changes -1.45V initial to -2.1V with change in time 4200s. the H concentration as time increases the Hion concentration increases till 1200s then it decreases. The Cl concentration decreases with time. The corresponding plot for chloride (Figure 10) shows a continuous decrease of chloride concentration close to the anode surface. This in turn decreases the production of chlorine and increases oxygen evolution. The pH value decreases with increase in time pH value goes 6.1 around 1000s. It can be used for dose planning and to kill the tumor tissue.

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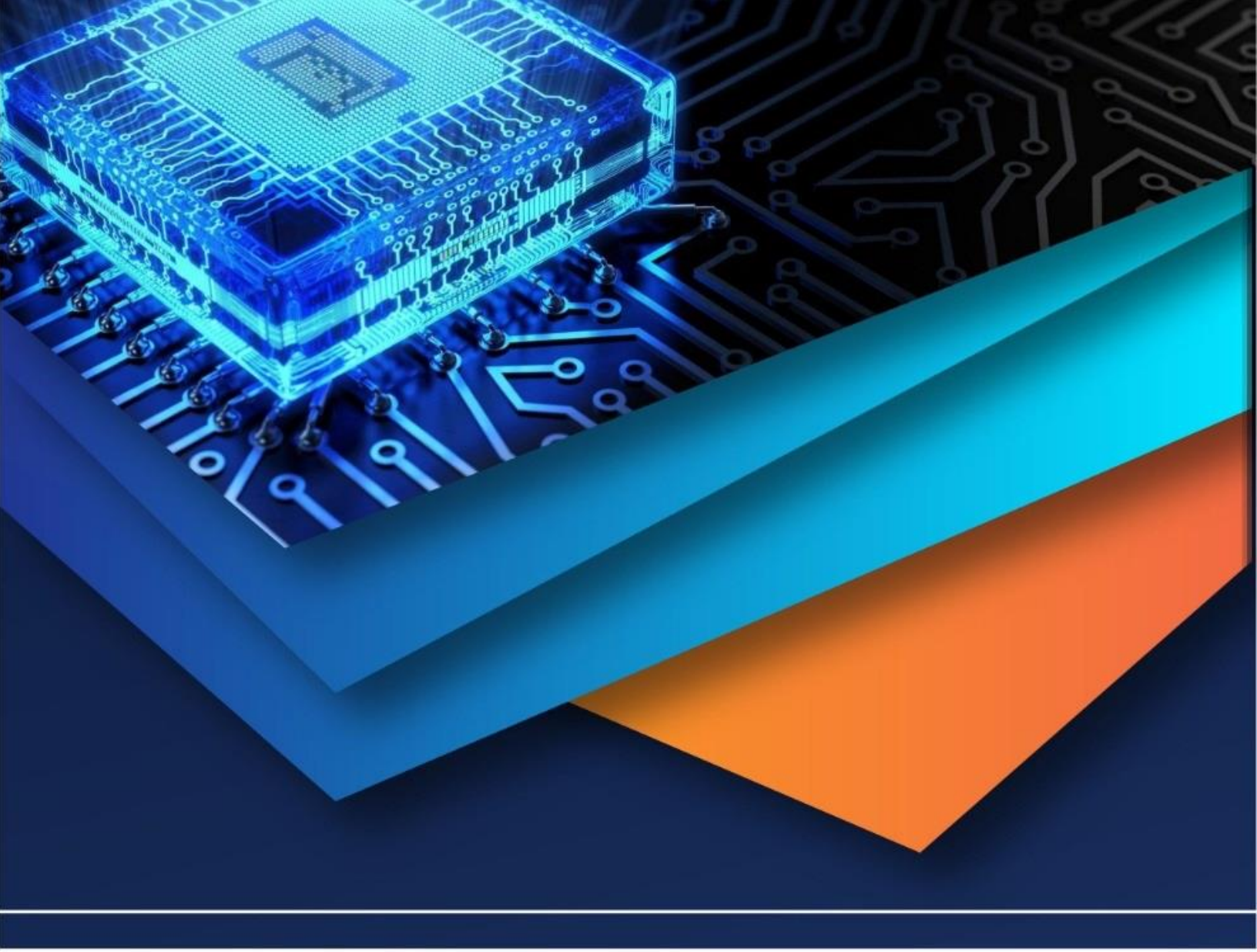

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