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STATISTICAL ANALYSIS OF PHYSICO-MECHANICAL PROPERTIES AND ELECTRICAL CONDUCTIVITY OF HIGH DENSITY POLYETHYLENE COMPOSITES

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ABSTRACT

Polymer composites are widely employed in engineering and industrial applications owing to their tunable properties, lightweight structure, and enhanced performance achieved through the incorporation of fillers and additives. High-density polyethylene (HDPE) composites are of particular interest due to their chemical resistance and mechanical strength; however, their non-polar nature often results in weak interfacial bonding with polar additives. This challenge highlights the need for systematic investigations of filler-matrix interactions.

This study examines the mechanical and electrical performance of HDPE-based composites incorporating calcite, graphite, ethyl vinyl acetate (EVA), elastomer, and crosslinker. The significance of this work lies in its multi-factorial approach, which evaluates the synergistic effects of multiple additives rather than relying on single-variable analyses. A total of twenty-six HDPE composite samples were fabricated using extrusion and injection molding processes designed through a statistical experimental plan. Samples were characterized by tensile strength, hardness, and electrical conductivity tests, alongside surface morphology analyses (SEM-EDS). Statistical evaluation was performed using analysis of variance (ANOVA) and response surface methodology (RSM) to determine the significance of parameters and their interactions. Results revealed that yield strength was best explained by the second-order model (quadratic), hardness by the first-order model (linear), while electrical conductivity did not fit the tested models. SEM-EDS further indicated poor dispersion and weak interfacial bonding between the HDPE matrix and additives. In conclusion, the findings emphasize the critical influence of additive type and proportion on the performance of HDPE composites.

Keywords: High density polyethylene composite, Response surface method, Electrical conductivity, Physical-mechanical properties, Electrostatic discharge.

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1 INTRODUCTION

Polyethylene (PE) is a type of thermoplastic widely used in engineering and industrial applications due to its properties such as molecular structure, chemical stability and ease of production. The molecular weight, crystal structure, and branching of the chains have a major impact on the mechanical and physical characteristics of PE, which is formed as a result of the polymerization of ethylene monomer. One of the PE types is HDPE, which is a thermoplastic with a hydrocarbon structure consisting of carbon and hydrogen atoms with a high molecular weight [1]. The main reasons why HDPE is preferred in industrial applications are; resistance to chemicals, low liquid absorption, high strength and impact resistance, lightness, and reshaping. HDPE can be improved in strength and thermal performance by chemically modifying it using various additives [2,3].

When combined with different fillers, HDPE, which is typically a non-polar polymer, might result in weak interfacial bonds. EVA is partially polar due to its vinyl acetate (VA) groups. Therefore, EVA can form an interphase between fillers and HDPE. In addition, it reduces phase separation by increasing dispersion [4]. Another additive is graphite, which is in the form of carbon and has high thermal conductivity. As is well known, HDPE has excellent electrical and thermal insulation. The graphite incorporation improves the heat transfer capacity of HDPE composite. This provides a great advantage for parts exposed to heat, such as electronic enclosures. In addition, the graphite component enhances the electrical conductivity of composite. Materials with electromagnetic interference shielding are used in applications such as static discharge [5]. Calcite (calcium carbonate, or $CaCO_3$) is one of the inorganic fillers that is commonly preferred in the industry because of its cost-effective, functional, and workability-enhancing properties. The utilization of high amounts of calcite may create a brittle structure and reduce impact strength. Therefore, it should be used at an appropriate rate (generally not exceeding 40%) and its compatibility with the polymer matrix can be improved with binders such as EVA [6]. As previously mentioned, HDPE is apolar, whereas the majority of fillers and additives are polar. This causes incompatibility and weak bonds at the interface. For this reason, maleic anhydride (MA) is preferred as a binding agent (compatibilizer) [7].

When electric charges cannot find a path to flow, they accumulate on the surface of the material, causing static charges to form. These charges start to flow freely from the material's surface when a conductive route forms. Such event is called electrostatic discharge (ESD). In order to prevent ESD events in industrial applications, antistatic products that dissipate

electrostatic charges are recommended [8]. The utilization of antistatic materials ensures minimum static charge generation. These materials, which dissipate static energy, ensure the flow and grounding of static charges on the surface. Such materials have a slower flow of charge compared to conductive materials. Sudden removal of static charges from a highly conductive surface can lead to arcing, electric shocks and various accidents. To prevent this, static charges should be slowly grounded from the material. As stated above, the charge flow in such materials takes longer than in conductive materials and thus electrostatic discharge does not occur suddenly [9,10].

Response Surface Method (RSM) and factor design, which are mathematical and statistical techniques widely used in modeling experiments, are a preferred method in analyzing problems and determining relationships between complex parameters [11]. With this method, it is possible to determine the order of importance of the parameters and optimize the process, and more sensitive and accurate results can be achieved with fewer experiments [12]. In the field of HDPE composites, rigorous statistical techniques have been instrumental in elucidating the effects of processing variables and filler–matrix interactions. For instance, Wimalasuriya et al. (2024) employed Grey Relational Analysis (GRA) to optimize the formulation of HDPE-glass composites and reported significant improvements in tensile strength and flexural properties, demonstrating the efficiency of GRA in multi-response optimization [13]. Similarly, Gnanadurai et al. (2019) applied Taguchi's L9 orthogonal design combined with GRA to water hyacinth fiber–reinforced HDPE composites; their findings indicated that fiber content and processing temperature were the most influential factors, leading to enhanced tensile and flexural strength, which were confirmed through ANOVA significance testing [14]. In addition, Sylajakumari et al. (2018) utilized Taguchi-based GRA for HDPE/TiO_2 nanocomposites and showed that optimization of filler loading and processing conditions substantially reduced wear rates while maintaining acceptable mechanical performance [15]. Collectively, these studies highlight not only the applicability of statistical approaches such as Taguchi design, ANOVA, and GRA but also their ability to identify critical parameters and optimize multiple performance criteria simultaneously. Building on this methodological foundation and demonstrated effectiveness, the present study employs ANOVA and regression-based modeling within a statistically designed framework to systematically analyze the mechanical and electrical behavior of HDPE composites.

Recent studies have reported that the physico-mechanical behavior and electrical conductivity of HDPE-based composites are strongly influenced by the type and amount of

fillers incorporated [16–18]. Expanded graphite reinforced HDPE composites, for example, exhibit the formation of conductive networks at the percolation threshold, leading to a sharp increase in electrical conductivity while simultaneously affecting the elastic and tensile responses of the material [18,19]. Similarly, carbon black-filled HDPE composites demonstrate typical percolation behavior, where conductivity increases with filler loading and morphology control, and recent studies emphasize strategies to reduce the percolation threshold while maintaining tensile and impact performance [20]. The addition of carbon nanotubes (CNTs) allows for high conductivity at relatively low filler contents; when well dispersed, CNTs also contribute to enhancements in elastic modulus and yield strength due to strong interfacial interactions [21]. On the other hand, inorganic fillers such as $CaCO_3$ can improve the stiffness and tensile properties of HDPE, although high loading levels may lead to interfacial debonding and embrittlement. In multi-component systems, these effects can be tuned through the combined use of different fillers and compatibilizers [22,23]. Overall, the literature highlights that achieving targeted electrostatic and mechanical performance in HDPE composites requires the careful optimization of filler type, concentration, dispersion, and processing conditions.

Although numerous studies have investigated the mechanical and electrical properties of polymer composites, the majority have focused on single-variable effects of fillers or additives, often neglecting the complex interactions that occur in multi-component systems. In particular, limited attention has been given to the systematic evaluation of HDPE composites containing multiple additives, where synergistic effect can play a decisive role in performance. The originality of the present study lies in its comprehensive approach, which simultaneously considers calcite, graphite, EVA, elastomer, and cross linker as key parameters within a statistically designed experimental framework. By employing RSM and ANOVA, the study not only identifies the individual effects of these additives but also elucidates their interactions, thereby providing a deeper understanding of the structure-property relationships in HDPE composites. This approach addresses a critical gap in the literature and offers valuable insights for optimizing the formulation of polymer composites for advanced engineering applications.

2 MATERIALS AND METHOD

2.1 Materials Used in Experiments

HDPE pellets were supplied from Petkim Petrochemicals facilities in Izmir. HDPE pellet, with the commercial code S0464, has a density of 0.961 g/cm^3 at 23˚C, a melting

temperature of 134˚C, a melt flow rate (190˚C/2.16 kg) of 0.36 g/10 min and a vicat softening point of 128˚C [24]. Ethyl vinyl acetate (EVA) with a density of 0.939 g/cm^3 and a vinyl acetate content of 18% was purchased from Plastdepo Inc., a commercial company in Bursa [25]. Graphite with a particle size of 200 mesh and a density of 2.19 g/cm^3 [26], calcite with a density of 2.75 g/cm^3 [27], maleic anhydride with a density of 1.48 g/cm^3 [28] used as elastomer material and crosslinker were supplied from various commercial companies.

2.2 Production of HDPE Composites

Using a co-rotating twin screw extruder, HDPE composites were produced by the melt blending technique (Gulnar, Türkiye). The screw diameter (D) of the extruder is 40 mm and the length/diameter (L/D) ratio is 16. The spindle rotation speed and molding pressure are 100 rpm and 6.7 bar, respectively. The mixing ratios listed in Table 1 were employed in the production of composites. To remove moisture from the HDPE and additives, the raw materials were dried for 24 hours at 80˚C prior to mixing. The extruder temperature was adjusted to 50, 200, 205, 210, 215, and 220˚C from the feeding zone to the outlet for the melt blending process, respectively. The molten rod-shaped material taken from the extruder was cooled in a water bath at ambient temperature and turned into granules (pellets) with the aid of a pelletizer. The twin screw extruder used in the experiments is shown in Figure 1. All pellets were subjected to mixing to ensure homogeneity before molding. The pelletized composites were then injection molded using a microinjection equipment (Xplore IM12, Netherlands) in accordance with the sample geometry appropriate for a variety of assays. The injection molding process was carried out under the conditions of 220˚C barrel temperature, 25˚C mold temperature and 7 bar injection pressure. Images of the produced samples are given in Figure 2.



Figure 1. Twin screw extruder used in experiments

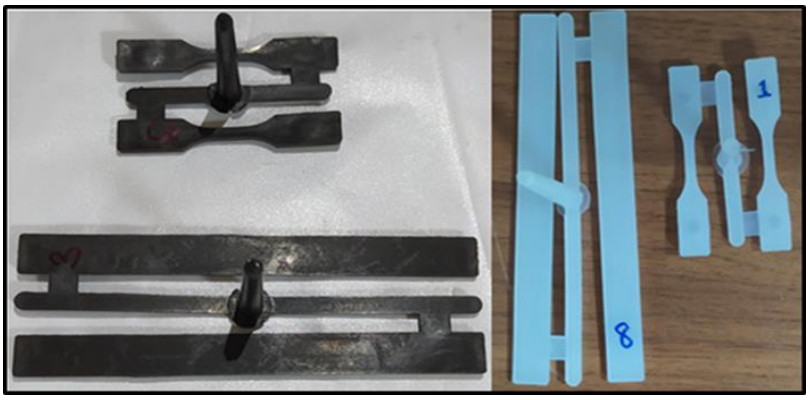


Figure 2. The produced samples

2.3 Response Surface Method (RSM) and Analysis of Variance (ANOVA)

In this study, the relationships between the types and proportions of additives incorporated into HDPE matrix and the resulting mechanical and electrical properties were evaluated by means of RSM. Instead of adopting a trial-and-error approach, RSM enabled the systematic design of experiments and the development of predictive models for hardness, yield strength, and electrical conductivity. A total of 26 experimental runs were generated using a multi-factor design, in which EVA (0-20 g), crosslinker (0-5 g), graphite (0-25 g), calcite (0-40 g), and elastomer (0-5 g) were selected as independent variables (Table 1). The responses obtained from these runs were subsequently fitted to first- and second-order models depending on the property under investigation.

The adequacy of the fitted models and the statistical significance of the factors were assessed by ANOVA using Design Expert 12 software. In this context, F and p values were used to determine the relative effect of each additive and their interactions on composite performance. Factors with p value < 0.05 were considered statistically significant contributors to the variation in the measured properties. Through this approach, not only the main effects of EVA, graphite, calcite, cross linker, and elastomer, however also their synergistic interactions were quantitatively evaluated. The results guided the identification of optimal formulation regions where targeted mechanical strength and electrostatic performance could be simultaneously achieved.

Table 1. Mixing ratios of produced samples (by weight %)

Sample	EVA (A)	MA (B)	Graphite (C)	Calcite (D)	Elastomer (E)
1	0	0	0	0	0
2	20	0	0	40	0
3	0	5	0	0	5
4	0	0	25	0	5
5	20	5	0	40	5
6	20	0	25	40	5
7	20	5	0	0	0
8	20	0	25	0	0
9	20	5	25	0	5
10	0	2.5	0	40	2.5
11	0	5	0	20	0
12	0	2.5	25	20	5
13	0	0	25	40	0
14	0	5	12	40	5
15	20	0	0	0	5
16	0	0	0	40	5
17	0	5	25	0	0
18	10	5	25	40	2.5
19	20	5	12.5	40	0
20	10	2.5	0	40	0
21	10	5	12.5	20	2.5
22	0	0	25	20	0
23	0	5	12.5	0	0
24	10	5	25	20	5
25	20	2.5	25	40	0
26	0	0	25	40	2.5

2.4 Test and Analysis

The surface morphological properties of pure HDPE and HDPE composites were determined by SEM-EDS analysis (Tescan, Maia3 Xmu). A Shore D hardness tester (Bareiss HPE II, Germany) was used to determine the hardness values of samples in accordance with ASTM D-2240. Tensile tests were carried out using a tensile testing machine (Shimadzu AGS-X) with a load capacity of 10 kN at a tensile speed of 5 mm/min according to the ASTM D-638 standard. Measurements of electrical conductivity were conducted using the four-point electrode method.

3 RESULTS AND DISCUSSIONS

3.1 Hardness

The hardness of a polymer composite depends on the hardness of the additive, its amount and distribution in the matrix. The hardness value of the pure sample (coded 1) was measured as 51.9 shore D. The hardness values of samples coded 10, 12, 13, 16 and 26 are higher than the pure sample. Considering the mixing ratios, these samples with high hardness values do not contain EVA, but contain high amounts of calcite or calcite/graphite. This increase may be due to the strong adhesion force between HDPE and additives and the higher hardness of the additives compared to HDPE [3,29,30]. It is also possible that the rise is due to the polymer chain mobility reduction of additives [31,32].

Equation (1) indicates that EVA is the most effective component, and that the hardness decreases as the amount of EVA in the mixture increases. Graphite and calcite factors have a positive effect on hardness, while changes in crosslinker and elastomer factors have a similar effect on hardness. In other words, the hardness values rise as the amount of graphite and calcite in the mixture increases (Table 2 and Figure 3). The degrees of influence of the components on hardness are EVA > calcite > graphite > elastomer > crosslinker from largest to smallest. Since the p-value is less than 0.05 and the regression coefficient (R^2 = 0.8730) value is high (close to 1), the proposed model is suitable for the current experimental study (Table 3) [33]. The optimum values of the components forming the mixture to reach the optimum hardness value are given in Figure 4.

$$Hardness = +47{,}30 - 3xA - 0{,}7906xB + 2xC + 2{,}70xD - 1{,}26xE - 1{,}07xAD + 1{,}31xBC + 1{,}76xDE \quad (1)$$

Table 2. Hardness test results

Sample	Hardness (Shore)	Sample	Hardness (Shore)	Sample	Hardness (Shore)
1	51.9	**11**	46.3	**21**	45.5
2	45.7	**12**	52.6	**22**	50.8
3	38.5	**13**	53.7	**23**	48.0
4	45.1	**14**	54.3	**24**	51.9
5	42.4	**15**	38.2	**25**	49.2
6	46.5	**16**	53.3	**26**	59.6
7	43.3	**17**	51.7		
8	46.3	**18**	48.0		
9	42.3	**19**	45.4		
10	52.4	**20**	48.1		

Table 3. ANOVA analysis of hardness results

Source	Sum of Squares	Degrees of Freedom (DF)	Mean Square	F-value	p-value	
Model	554.68	8	69.34	14.61	< 0.0001	significant
A-EVA	183.98	1	183.98	38.76	< 0.0001	
B-C.linker	12.72	1	12.72	2.68	0.1200	
C-Graphite	85.55	1	85.55	18.02	0.0005	
D-Calcite	145.73	1	145.73	30.70	< 0.0001	
E-Elastomer	33.41	1	33.41	7.04	0.0167	
AD	20.42	1	20.42	4.30	0.0536	
BC	29.61	1	29.61	6.24	0.0231	
DE	53.02	1	53.02	11.17	0.0039	
Residual	80.69	17	4.75			
Cor Total	635.37	25				
Std. Dev.		2.18	**R^2**		0.8730	
Mean		48.12	**Adjusted R^2**		0.8132	
C.V. %		4.53	**Predicted R^2**		0.7269	
			Adeq Precision		12.5886	

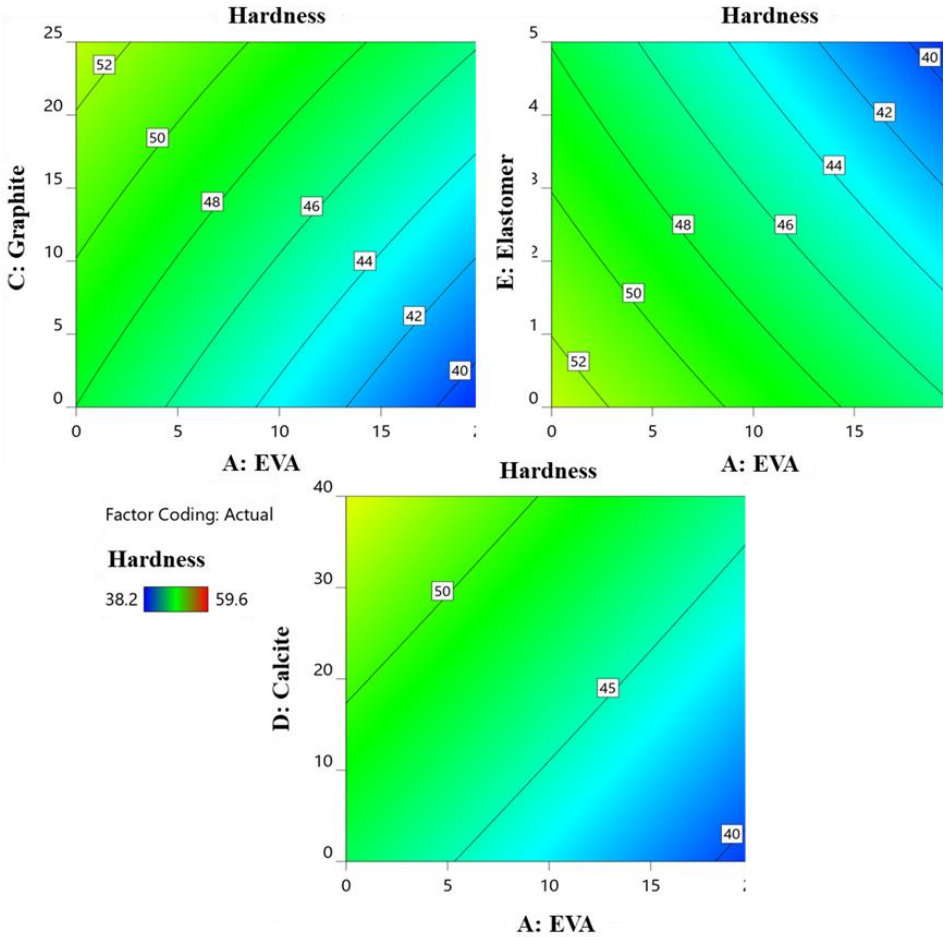


Figure 3. Effects of elastomer, EVA, graphite, calcite and cross linker content on hardness values

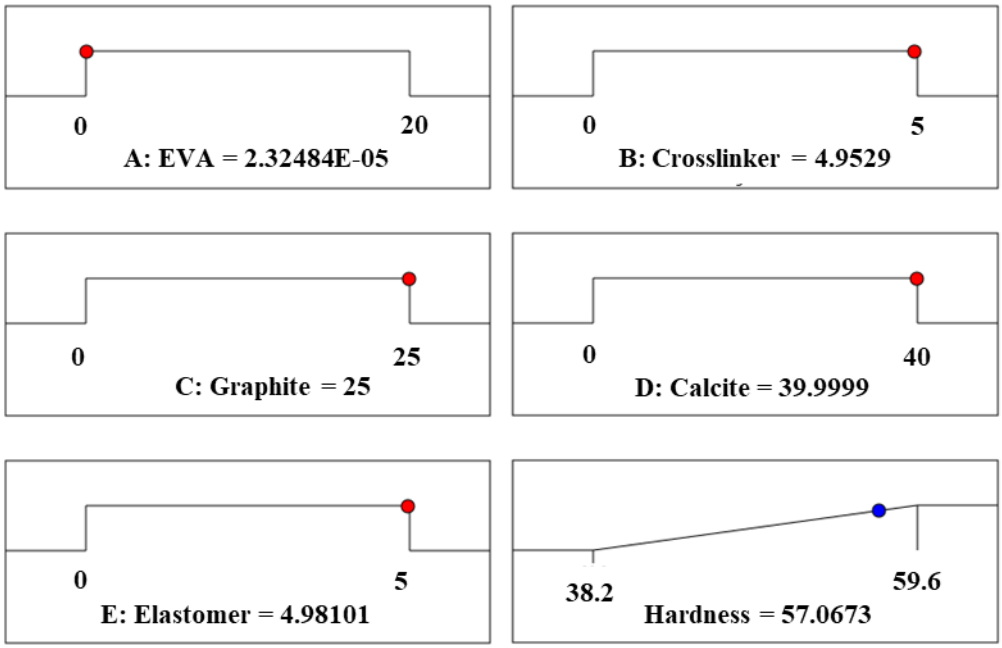


Figure 4. Optimum values of components for highest hardness values

3.2 Yield Strength

The yield strength values obtained were first analyzed according to the 2FI model. However, no agreement was observed between the experimental data and the relevant model. Therefore, the experimental data were analyzed based on the quadratic model. While the lowest tensile strength (5.20 MPa) was reached in samples coded 13 and 14, the highest tensile strength value of 10.94 MPa was obtained in sample coded 11 (Table 4). According to ANOVA analysis data, the most effective component on yield strength is EVA. The yield strength values are positively impacted by a rise in crosslinker and elastomer components, whereas the inverse is true for other components. The degree of influence of the components on the yield strength may be listed as EVA > calcite > crosslinker > elastomer > graphite (Equation 2). ANOVA analysis results show that the proposed model is compatible with the experimental findings (p value = 0.0450 and R^2 = 0.8152) (Table 5). The findings in Figure 5 demonstrate that a high elastomer and EVA content results in the maximum yield strength. On the other hand, if the elastomer content is low and the EVA amount is high, the yield strength decreases to 10 MPa. To obtain optimum yield strength (8.272 MPa), the mixture components are expected to be EVA (2.79 g), crosslinker (2.49 g), graphite (16.46 g), calcite (37.51 g) and elastomer (4.03 g) (Figure 6).

Table 4. Yield strength test results

Sample	Yield strength (MPa)	Sample	Yield strength (MPa)	Sample	Yield strength (MPa)
1	9.39	**11**	10.94	**21**	9.97
2	6.35	**12**	10.74	**22**	8.79
3	9.38	**13**	5.20	**23**	5.70
4	9.67	**14**	5.20	**24**	9.20
5	4.82	**15**	7.12	**25**	5.20
6	5.70	**16**	8.33	**26**	6.21
7	7.21	**17**	9.20		
8	9.26	**18**	10.74		
9	6.21	**19**	9.60		
10	8.10	**20**	7.08		

$$Yield\ strength\ (MPa) = +9{,}41 - 0{,}5031xA + 0{,}3712xB - 0{,}1574xC - 0{,}4077xD + 0{,}4244xE + 0{,}3077xAB + 1{,}15xAC + 0{,}5282xAD - 1{,}78xAE + 0{,}6806xBC + 0{,}9348xBD - 0{,}1635xBE - 0{,}3133xCD + 0{,}5xDE - 2{,}26xD2 \quad (2)$$

Table 5. ANOVA analysis of yield strength results

Source	Sum of Squares	Degrees of Freedom (DF)	Mean Square	F-value	p-value	
Model	79.28	15	5.29	2.94	0.0450	significant
A-EVA	3.50	1	3.50	1.95	0.1928	
B-C.linker	1.96	1	1.96	1.09	0.3203	
C-Graphite	0.2899	1	0.2899	0.1613	0.6964	
D-Calcite	2.35	1	2.35	1.31	0.2795	
E-Elastomer	1.15	1	1.15	0.6391	0.4426	
AB	1.24	1	1.24	0.6908	0.4253	
AC	15.04	1	15.04	8.37	0.0160	
AD	3.96	1	3.96	2.20	0.1685	
AE	22.54	1	22.54	12.54	0.0053	
BC	4.20	1	4.20	2.34	0.1573	
BD	11.28	1	11.28	6.28	0.0311	
BE	0.1478	1	0.1478	0.0822	0.7801	
CD	1.14	1	1.14	0.6365	0.4435	
DE	2.00	1	2.00	1.11	0.3160	
D^2	16.48	1	16.48	9.17	0.0127	
Residual	17.97	10	1.80			
Cor Total	97.25	25				
Std. Dev.		1.34	**R^2**		0.8152	
Mean		7.90	**Adjusted R^2**		0.5381	
C.V. %		16.97	**Predicted R^2**		0.9500	
			Adeq Precision		6.0355	

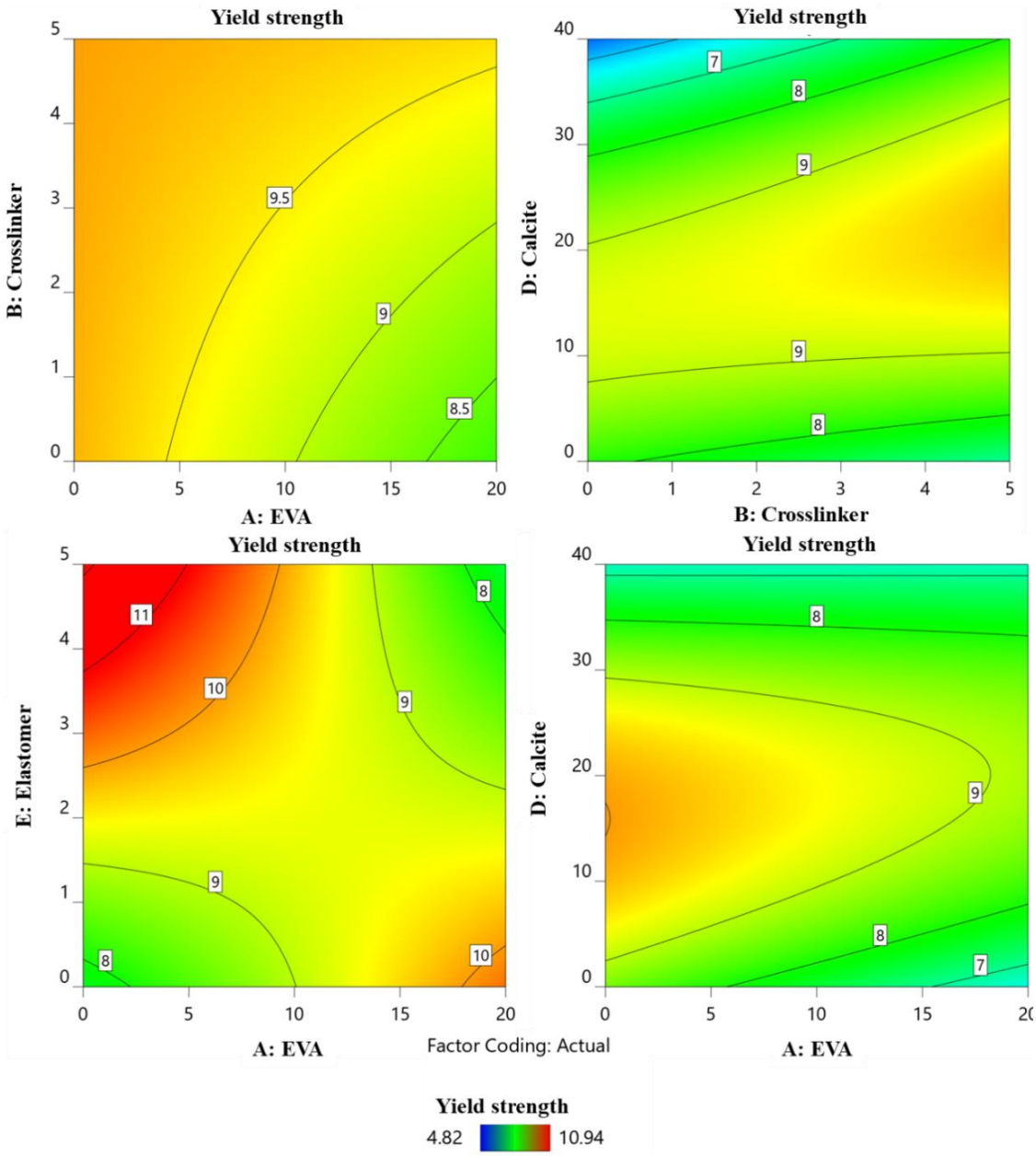


Figure 5. Effects of elastomer, EVA, cross linker and calcite content on yield strength values

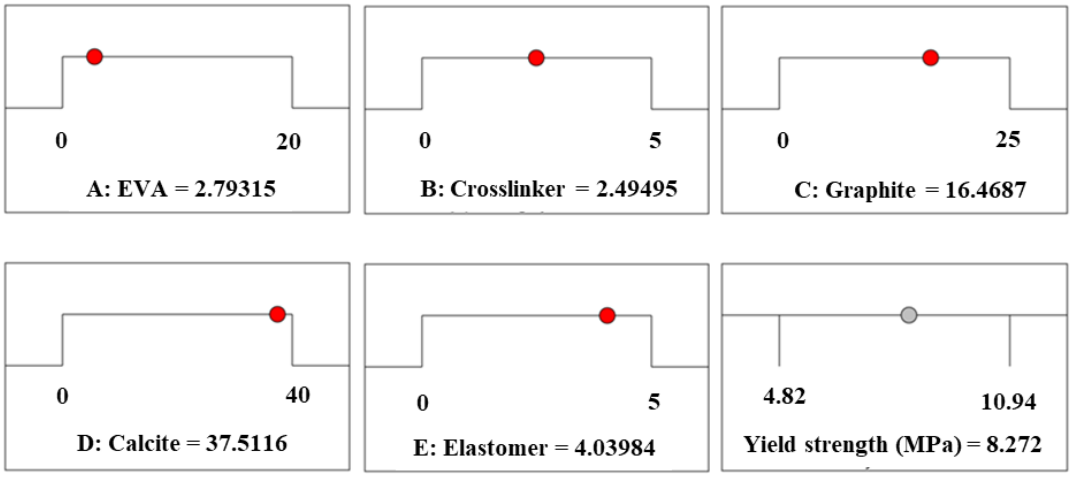


Figure 6. Optimum values of components for highest yield strength values

3.3 Electrical Resistance

Electrical resistance measurements of the samples were carried out using a 4-point electrical conductivity meter (in the range of 0 to 2 volts and 0 to 10 nA). Electrical resistance measurement results were not compatible with any model (Table 6). There is no significant difference between the minimum electrical resistance values of the samples. However, the maximum electrical resistance values varied between 14.93×10^9 ohm and 23.51×10^9 ohm. The findings indicate that samples containing graphite and calcite generally have higher electrical resistance values. This is thought to be due to the graphite in the matrix not being distributed homogeneously.

Table 6. Electrical resistance measurement results ($x10^9$ ohm)

Sample	min.	max.	Sample	min.	max.	Sample	min.	max.
1	6.17	16.45	**11**	6.88	22.92	**21**	7.00	23.34
2	6.64	23.24	**12**	7.03	23.44	**22**	7.03	23.44
3	6.06	15.36	**13**	5.98	16.44	**23**	6.98	23.27
4	6.63	23.21	**14**	6.63	23.22	**24**	6.66	23.32
5	6.34	16.12	**15**	6.92	23.07	**25**	6.96	23.19
6	6.14	14.93	**16**	6.60	23.11	**26**	7.02	23.41
7	6.88	22.92	**17**	6.72	23.51			
8	6.65	23.29	**18**	6.84	22.79			
9	6.94	23.12	**19**	6.91	23.03			
10	6.07	16.69	**20**	6.98	23.28			

3.4 SEM and EDS Analysis

SEM-EDS analyses of the surface morphologies of the samples in the experimental design (coded 1, 2, 4, 11, 18 and 25) are presented (Figure 7 and Figure 8). Analyses were performed on the fracture surfaces of the samples. After the tensile test, the fiber structure of pure HDPE was deformed. The presence of carbon element in the HDPE structure was confirmed by EDS analysis. Due to the poor matrix-particle contact within the HDPE matrix, gaps appeared around the particles on the surface of samples (coded 2, 4, 11, and 18) that included varying amounts of graphite and calcite. The weak interface caused the particles in the HDPE matrix to have low resistance to the applied force, resulting in the formation of voids. In samples containing graphite and calcite (coded 2, 4 and 11), it is observed that the particles are not distributed homogeneously within the matrix and are clustered. Composite samples containing 25% graphite and 40% calcite also have a similar surface morphology.

On the other hand, the fibrous structure observed in the above samples was not observed in the sample code 25 (20% EVA, 2.5% cross linker, 25% graphite and 40% calcite added). This can be attributed to the brittle fracture behavior of the sample due to the increase in filler content.

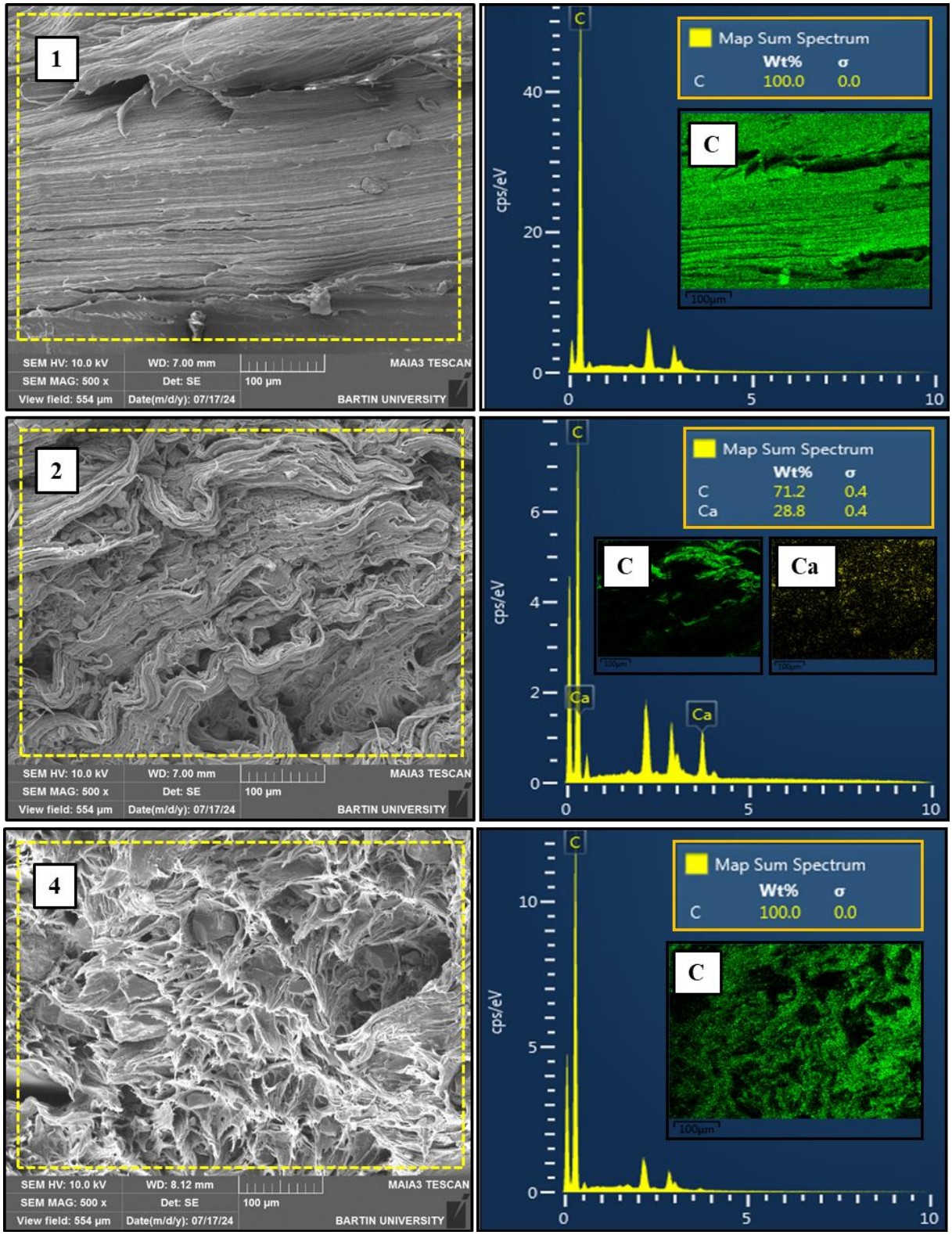


Figure 7. SEM images, EDS and mapping analyses of samples coded 1, 2 and 4

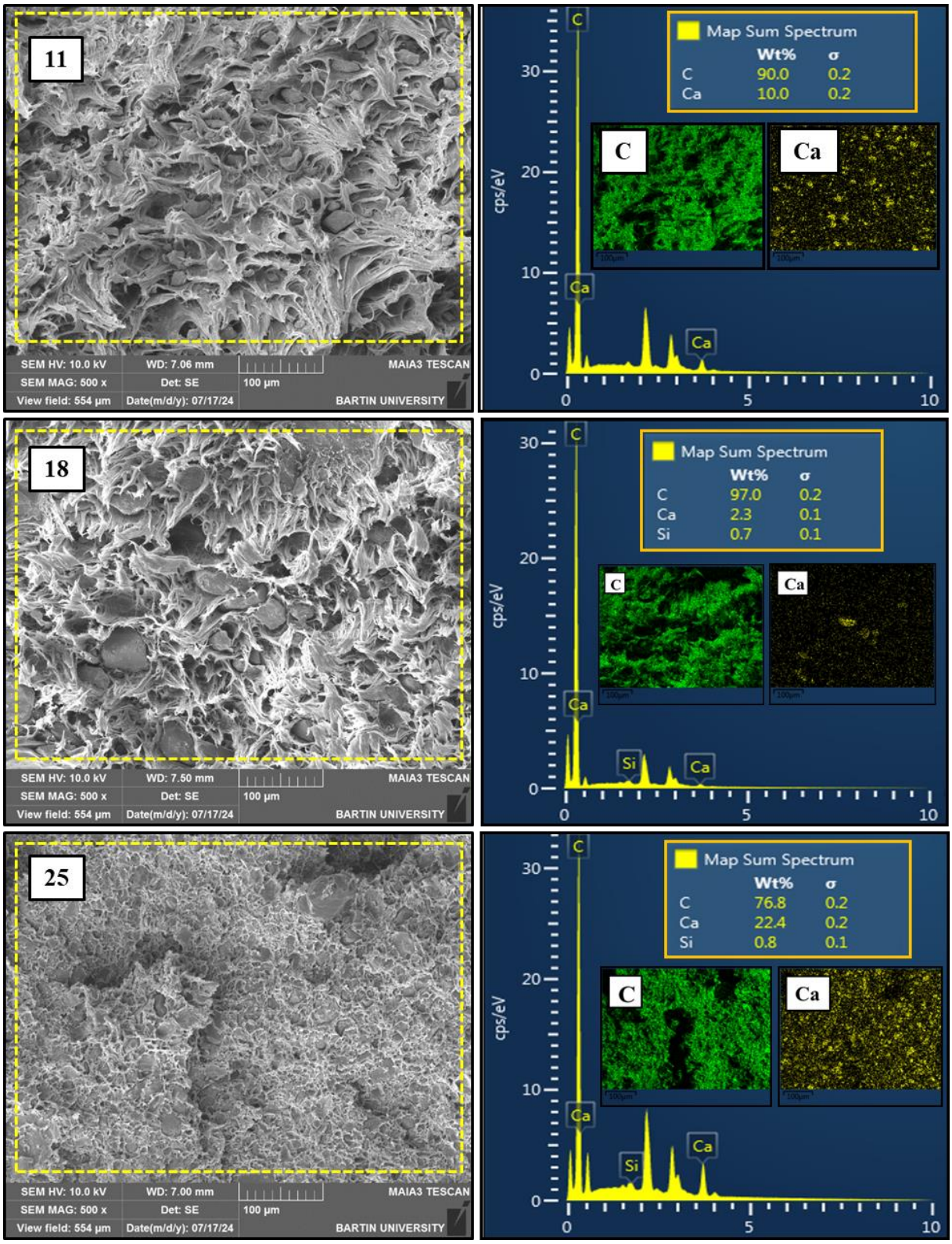


Figure 8. SEM images, EDS and mapping analyses of samples coded 11, 18 and 25

4 CONCLUSIONS

This study examined the influence of calcite, graphite, EVA, elastomer, and cross linker on the mechanical and electrical properties of HDPE composites using a statistically designed experimental approach. The analysis showed that yield strength was best explained by a quadratic model, hardness by a linear model, while electrical conductivity did not conform to the tested regression models. Surface analyses further revealed poor dispersion and weak interfacial adhesion between the HDPE matrix and the additives. These findings suggest that while mechanical properties can be partially optimized through additive combinations, electrical performance remains more complex and less predictable.

Another implication of this work is that additive interactions in HDPE composites are highly non-linear and cannot be fully captured by single-variable analyses. The weak filler-matrix interface observed indicates the necessity of surface modification or compatibilizers to enhance bonding and dispersion, which may improve both mechanical integrity and functional performance. Furthermore, the inability to establish a statistically valid predictive model for electrical conductivity points to the need for incorporating additional parameters, such as filler particle size distribution, morphology, and percolation threshold effects, into future experimental designs.

Future research directions should therefore move toward integrated optimization strategies. Combining statistical tools such as RSM, Taguchi method, and GRA with computational approaches, including finite element simulations and machine learning-based predictive models, could provide more robust insights into structure-property relationships. Moreover, long-term durability assessments, including thermal aging, fatigue, and environmental exposure tests, are needed to establish the real-world applicability of optimized HDPE composites.

In conclusion, while this study establishes a methodological and experimental foundation for the statistical optimization of HDPE composites, it also highlights the necessity of addressing interfacial compatibility and incorporating broader performance parameters in future investigations. By doing so, the path toward designing multifunctional polymer composites with tailored properties for advanced engineering applications can be more effectively realized.

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Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

Contributions of the Authors

Ecem Torun: Writing-review editing, Writing-original draft, Methodology, Investigation. Ali Yaras: Writing-review editing, Writing-original draft, Supervision, Conceptualization. Bilal Demirel: Investigation, Data curation, Writing-review & editing, Writing-original draft. Bilal Kursuncu: Formal Analysis, Software, Writing-review & editing, Writing-original draft

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