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**Índice Vol. 10 Núm. 3 (2026)**

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## Índice Vol. 10 Núm. 3 (2026)

**Transformación material en la vivienda chontal, caso de estudio: Huimango, Cunduacán, Tabasco** 1-12
Campos-de Dios P.C.[1*], Govea-Ek A.[1]

**Inhibición de corrosión en acero API 5L-X52 mediante extracto etanólico de *Tradescantia spathacea Sw*** 13-25
Estrada-Hernández G. V., Figueroa-Ramírez S.J.[*], Sierra-Grajeda J.M.T., Santis Espinosa L.F., Benavides O., De la Cruz-May L.

**Efecto de las nanoparticulas metálicas sobre el crecimiento de la microalga *Coelastrella sp*. para la producción de biocombustible** 26-37
Santis-Espinosa L.F[1*], Figueroa-Ramírez S.J.[1], Vargas-Estrada L.[2], López-Vidaña E.C.[3]

**Influence of dopant material on a silicone polymer subjected to low-pressure air plasma treatments** 38-52
Alarcón-Hernández F.B.[1]*, Fuentes-Albarrán M. del C.[1], Paredes-Olguín M.[2], Avelar-Domínguez F.[1], Gadea-Pacheco J.L.[1], Sandoval-González A.[3]

**Cambio en la producción de potencia empleando $Na_2SO_4$ en el cátodo de una celda de combustible microbiana** 53-60
Fuentes-Albarrán M. del C.[1]*, Alarcón-Hernández F.B.[1], Cornejo-Tapia C.P.[1], Sandoval-González A.[2]

**Estudio exploratorio del contenido de etanol en la pulpa de la T*hevetia peruviana* (Pers.) K. Schum en Yucatán, México** 61-79
Koh-Echeverría L.E.[1], Amado-Méndez K.[2], Díaz-Ballote, L.F.J.[2], Herrera-Zamora, D.M.[2]*

**Determinación de carbohidratos por HPLC: comparación de detectores UV-Vis *vs* índice de refracción** 80-93
Fernández-Orozco I.V.[1], Grijalva-Haro M.I.[2], Madrigal-Diaz S.C.[1], Ojeda-Morales M.E.[1], Díaz-Reyes C.C.[1], García-López S.[1], Juárez-Zirate S.J.[3]*

**Efecto de un plasma pulsado de aire en las propiedades superficiales de caucho butílico** 94-103
Alarcón-Hernández F.B.[1]*, Fuentes-Albarrán M. del C.[1], Garay-Galicia J.A.[1], Sandoval-Gonzáles A.[2]

**Estudio del tiempo de fraguado en pastas de cemento con sustitución parcial por biocemento de ostión** 104-116
Segundo-Díaz T. de J.[1], Mora-Ortiz R.S.[1]*, Díaz-Alvarado S.A.[1], Ramón-de los Santos C. [2]

**Estudio teórico de un captador solar de aire con y sin material de cambio de fase** 117-128
Álvarez-Alor B.[1*], Cruz-Valdez J. A. [2], Montalvo D. [3], López-Santos F.[1], Alvarado-Méndez P. E.[4], Zetina-Ríos I. I.[5].

Índice Vol. 10 Núm. 3 (2026)

# Efecto de un plasma pulsado de aire en las propiedades superficiales de caucho butílico

# Effect of a pulsed air plasma on the surface properties of butyl rubber

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## ABSTRACT

The use of pulsed air plasma was evaluated as an option for modifying the physical properties of butyl rubber, with an emphasis on controlled surface wear. Commercial rubber samples (1.0 cm × 5.0 cm) obtained from bicycle inner tubes were used. All samples exposed to plasma were previously subjected to a 44 day acetone pretreatment to analyse the effects of the solvent before plasma treatment. The experimental design included 21 samples (three controls, three samples subjected to acetone bath pretreatment, and 15 samples subjected to acetone bath pretreatment plus air plasma exposure). Measurements of mass, contact angle, hardness, and elasticity were performed before and after treatment. Plasma was applied in a vacuum chamber using a radiofrequency generator (Cesar 136 RF, 600 W output), an impedance matching network (Navío), and a vacuum pump (Labconco model 117LA65312906). The conditions were: 250 W power, 3 cm electrode spacing, 10 minutes exposure time, and pulse frequencies between 10 000 and 30 000 Hz. The results show mass loss (2.30% at 15,000 Hz, 1.64% at 30,000 Hz) and a decrease in hydrophobicity (130.11° at 15,000 Hz, 100.75° at 30,000 Hz). Furthermore, mechanical testing showed an increase in hardness (54.00 HA at 20,000 Hz, 52.17 HA at 30,000 Hz), along with changes in Young's modulus (3.76 MPa at 20,000 Hz, 2.81 MPa at both 30,000 and 10,000 Hz). It is concluded that pulsed air plasma is an effective alternative for the frequency-dependent surface modification of butyl rubber. Such changes may have potential applications in recycling and materials bonding.

**Keywords:** Degradation**;** elasticity; hardness; hydrophobicity; polymer.

## INTRODUCTION

Butyl rubber has been commercially produced since 1942. It is an elastomeric polymer widely used in adhesives and sealants as a binder and adhesion modifier. This material exhibits special properties, including low gas permeability, good water and chemical resistance, and poor oil resistance [1]. Synthetic butyl rubber can be used over a wide temperature range, making it an ideal



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candidate for applications such as tire inner tubes, roof membranes, and refrigeration system seals [2]. However, when used at interfaces where adhesion, coating, or surface interaction with other materials are critical, limitations arise due to its relatively inert nature. From this perspective, surface treatment is a key strategy for enhancing compatibility with adhesives, coatings, or substrates, thereby optimising functionality in systems such as gaskets, membranes, linings, or shock absorbers. It is highly relevant to experimentally investigate how advanced surface modification techniques can transform the surface layer of butyl rubber without compromising its fundamental properties.

The application of pulsed plasma in an air atmosphere presents itself as a clean, controllable, and potentially scalable alternative that can generate functional groups on the rubber surface [3, 4] and increase surface energy, thereby promoting adhesion, facilitating subsequent coating, and enhancing wettability [5, 6]. It has also been observed that, in rubber elastomers treated with atmospheric plasma, the surface energy increases by 58 % and the polar component by 95 % [7, 8], which has a positive impact on coating adhesion and ageing behaviour [7, 9]. Given the previously mentioned characteristics of the effects and manageability of low-pressure air plasma used as a treatment to modify surfaces in general, and in particular synthetic rubber samples, this research aims to analyse, from a first approach, the effect of a pulsed low-pressure air plasma on the surface properties of vulcanised butyl rubber, evaluating parameters such as: mass loss, hydrophobicity, elasticity and hardness, in order to determine the optimal treatment conditions and their impact on the functionality of the material's surface.

## EXPERIMENTAL METHODOLOGY

**Butyl Rubber.** Commercial butyl rubber (used in bicycle inner tubes) was used in samples with dimensions of 1.0 cm × 5.0 cm (**Figure 1**).

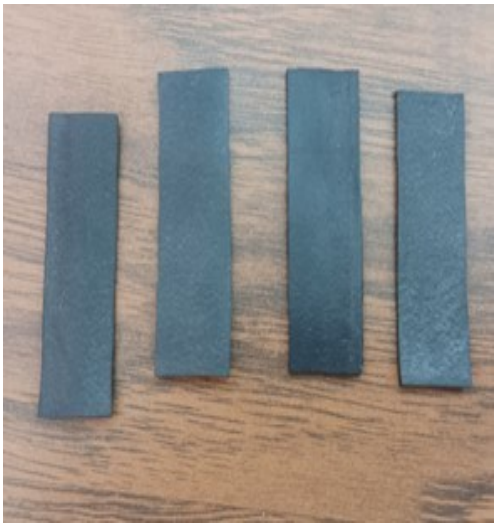


**Figure 1**. Butyl rubber samples



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All samples were washed with soap and water before any processing. 21 samples were considered (three controls, three subjected to acetone bath pretreatment, and 15 subjected to acetone bath pretreatment plus exposure to air plasma).

**Acetone Pretreatment.** The acetone bath pretreatment consisted of immersing 18 rubber samples in a sealed glass container of acetone for 44 days. This was done to modify and weaken the material's polymer network. After this time, the samples were placed in containers at room temperature (26 °C) and in air to allow the acetone to evaporate. The evaporation time for each sample was 30 minutes.

**Plasma Treatment.** The plasma treatments consisted of exposing each sample of interest, one at a time, to a low-pressure air plasma (2 Torr). The plasma generation parameters were fixed (Power: 250 W), as were the exposure time (10 minutes) and the electrode separation distance (3 cm). The variable that was modified in each treatment was the plasma generation frequency. **Table 1** presents the values considered for each treatment.

**Table 1**. Plasma frequency values according to treatment

| Treatment | Frequency (Hz) |
|---|---|
| 1 | 10 000 |
| 2 | 15 000 |
| 3 | 20 000 |
| 4 | 25 000 |
| 5 | 30 000 |
| Control | Without treatment |
| Acetone pretreatment | Without plasma treatment |

**Experimental Apparatus. Figure 2** shows a schematic of the experimental apparatus used. It consists of a hermetically sealed glass chamber, two aluminium electrodes, a vacuum system (digital vacuum gauge: CPS, vacuum pump: LABCONCO), and a radiofrequency plasma generator (Cesar 136 RF Output 600 W).

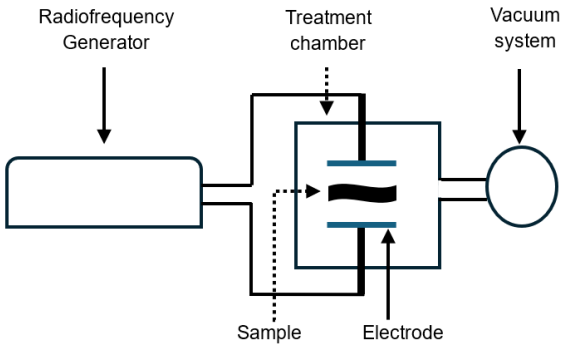



**Figure 2**. Schematic of experimental apparatus for plasma treatment

The sample (butyl rubber) is placed between the two electrodes, and a vacuum is applied (2 Torr). The plasma is then generated according to the treatment specifications. Each sample is exposed to the plasma for 10 minutes. After this time, the treatment is stopped, and the sample is removed.


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The above procedure is repeated for subsequent samples. Three repetitions of each treatment were performed. The reported results are the average value of the three repetitions for each variable of interest.

The experimental conditions were defined to conduct a controlled, preliminary study, keeping pressure, power, treatment time, and electrode spacing constant to isolate the effect of frequency as the main variable. These values were chosen to generate surface modifications through reactive species without significantly affecting the material. Furthermore, the frequency range was selected to assess its influence on plasma-surface interactions. The inclusion of control samples and samples pretreated in acetone is intended to establish comparisons and attribute the observed changes exclusively to the plasma treatment.

**Measurement of the variable of interest.** The effect of plasma on the samples was determined by measuring mass change (analytical balance: AE-ADAM, model PW254), hydrophobicity (sessile droplet technique, digital microscope: Microscope 1600X Black), hardness (durometer: Shore A Durometer, 0-100 HA), and elasticity (dynamometer MS-A09L).

Specifically, hydrophobicity was determined by measuring the external angle between the surface of interest and a droplet of distilled water (a slight angle ($\theta < 90°$) indicates a hydrophobic surface, a large angle ($\boldsymbol{\theta > 90°}$) indicates a hydrophilic surface), as shown in **Figure 3.**

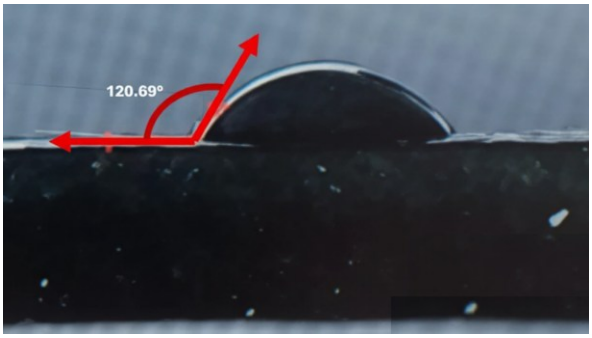



**Figure 3**. Measurement of the contact angle (hydrophobicity) between a drop of distilled water and a plasma-treated butyl rubber surface.

Elasticity was determined using the equation for calculating Young's Modulus:

$$E = \frac{F/A}{\Delta l/l_0}$$

Where:

E: Young's modulus, F: force applied to the sample, A: surface area of the sample, Δl: change in length, and $l_0$: initial length of the sample. Materials with higher Young's modulus have greater stiffness and less elastic deformability under applied load.


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## RESULTS

The results of the behaviour of the measured variables as a function of each defined treatment are presented.

**Mass loss. Figure 4** shows the results of the percentage mass loss. The data from the butyl rubber samples subjected to low-pressure air plasma treatments show an increase in surface degradation as the treatment frequency decreases.

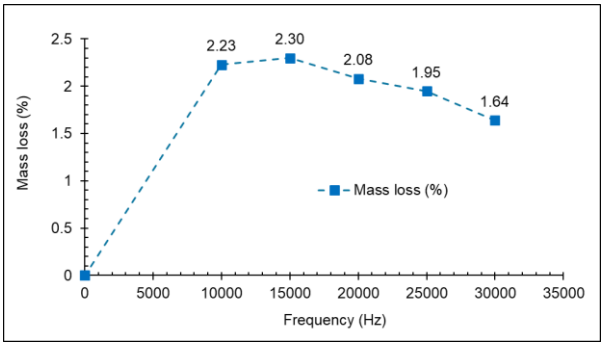



**Figure 4**. Mass change of the treated samples in percentage terms

All samples lost a certain percentage of mass; however, it was observed that as the plasma pulse frequency increased, the loss decreased. The maximum percentage loss corresponded to plasma generated at 15 000 Hz, and the minimum at 30 000 Hz. For the samples pretreated with acetone, there was no measurable mass loss.

**Hydrophobicity.** The hydrophobicity of a material can be determined in terms of the contact angle between a drop of distilled water and the surface of interest. In this case, a larger contact angle indicates lower hydrophobicity, since a smaller angle indicates a lower affinity of the liquid for the solid surface.

From **Figure 5**, it can be seen that the change in contact angle measured in the butyl rubber samples treated with plasma at different frequencies, shows an initial tendency to increase the angle with respect to the control sample (98.39°) and the one treated with acetone (96.87°), reaching a maximum value of 130.11° at a frequency of 15 000 Hz.

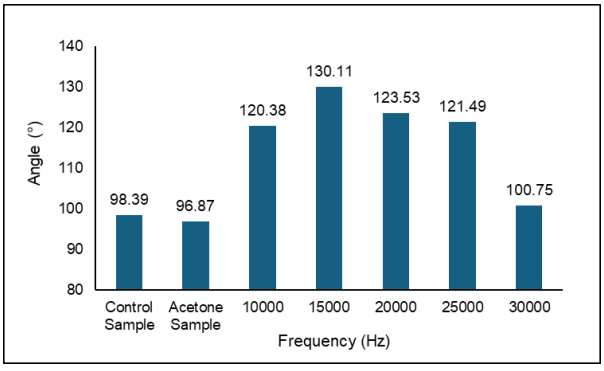



**Figure 5.** Modification of the contact angle (hydrophobicity) of treated samples as a function of plasma treatments



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A progressive decrease in the angle is also evident as the frequency increases, reaching a value of 100.75° at 30 000 Hz, which is close to that of the untreated material.

**Hardness.** The hardness data shown in **Figure 6** for the butyl rubber samples treated with plasma at different frequencies reveal a moderate variation compared to the control sample (51.33 HA) and the sample pretreated with acetone (52.00 HA).

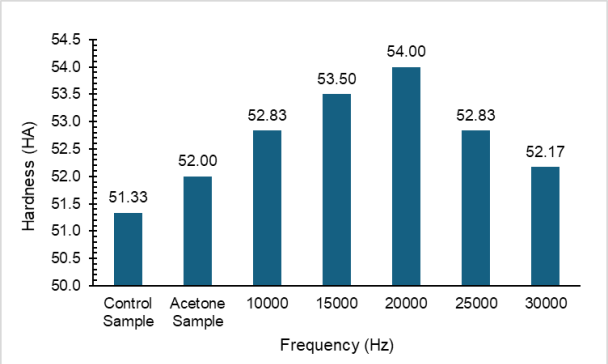



**Figure 6.** Variation of hardness values in plasma-treated samples as a function of plasma frequency

A progressive increase in hardness is observed with increasing plasma frequency, reaching a maximum value of 54.00 HA at 20 000 Hz. A slight decrease in the variable of interest then occurs as the frequency increases, reaching a value of 52.17 HA at 30 000 Hz. Overall, the results indicate that the hardness of butyl rubber can be modulated by plasma treatments, with frequency being a key parameter for controlling the material's surface mechanical properties with respect to this variable.

**Elasticity.** The study of the change in elasticity (Young's Modulus) of the polymer of interest (butyl rubber) exposed to a plasma of different generation frequencies (increasing frequencies) shows that this variable varies non-linearly with the plasma frequency, resulting in points of greater stiffness at specific frequencies, as can be seen in **Figure 7.**

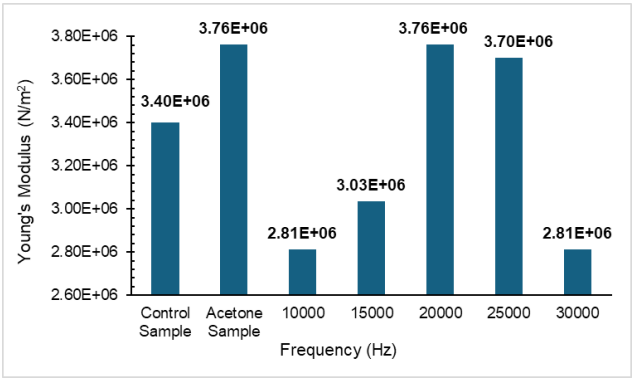



**Figure 7.** Modification of the elasticity (Young's modulus) of butyl rubber as a function of plasma treatments



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The reference values, designated as the Control Sample and Acetone Sample, showed Young's moduli of 3.4 MPa and 3.76 MPa, respectively, indicating an initial decrease in elasticity following acetone treatment. Furthermore, when the material was subjected to plasma at 10 000 Hz, the Young's modulus decreased to 2.81 MPa, suggesting a reduction in the material's stiffness. At 15 000 Hz, the value increased slightly to 3.03 MPa, but remained below the values of both the control sample and the acetone-treated sample. A peak of 3.76 MPa was observed at 20 000 Hz, matching the result observed with the acetone-treated sample. Subsequently, at 25 000 Hz, the modulus was 3.70 MPa, before decreasing again to 2.81 MPa at 30 000 Hz.

## DISCUSSION

It is known that air plasma treatment generates reactive species (positive ions, negative ions, and radicals) that interact with the surface of the samples of interest, causing various physicochemical processes. These processes include reaction with surface contaminants and additives of the samples, the breaking of bonds in the outer layer of the polymer with the generation of free radicals, the incorporation of oxygenated functional groups (–OH, >C=O, –COOH), the possible appearance of surface crosslinking or chain cleavage degradation, and the modification of surface roughness. Some studies have shown that plasma exposure can increase the surface hardness of samples, attributed to densification from polymer crosslinking [13]. Although adding oxygenated groups tends to reduce hydrophobicity, partial hydrophobic recovery has been observed over time, a phenomenon known as hydrophobic recovery [7]. As reported in other studies, these transformations induce characteristic effects in the samples. These include increased surface energy (leading to higher wettability) [11], variations in roughness, changes in surface crosslinking density (resulting in increased hardness) [12], and mass losses due to the removal of contaminants, additives, or polymer fragments.

The nature of the dominant effect depends on parameters such as exposure time, the type of gas or plasma, and the ionisation power or density (Initially, the formation of functional groups predominates, while at longer times or higher power levels, crosslinking or degradation processes may prevail [6, 12]).

Some studies have shown that plasma exposure can increase the surface hardness of samples, attributed to densification from polymer crosslinking [13]. Although adding oxygenated groups tends to reduce hydrophobicity, partial hydrophobic recovery has been observed over time, a phenomenon known as hydrophobic recovery [7].

In particular, the behaviour observed in the treatment of butyl rubber using plasmas of different frequencies can be explained by considering the greater interaction between the ionised gas and the polymer surface under lower frequency conditions. At such (low) frequencies, the interaction time of the active species (ions, free radicals, electrons, and excited molecules) is longer, allowing for more efficient energy transfer to the samples, facilitating ablation processes, surface oxidation, and cleavage of C–H and C–C bonds in the polymer chain [6, 12, and 14]. This phenomenon explains why mass loss and surface modification are more relevant at frequencies between 10 000


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and 15 000 Hz, while at higher frequencies (30 000 Hz), the duration of the interaction decreases, limiting the effects of exposure [15].

The most significant mass loss occurred in the 15 000 Hz sample (implying a strong cleaning or removal process), and the generation of a high density of oxygenated groups on the surface would be expected, leading to a decrease in hydrophobicity [10]. Logically, the lower hydrophobicity coincides with the frequency of maximum mass removal (cleaning of hydrophobic additives such as waxes and oils). Exposure of the polymer matrix, along with the formation of polar groups, reduces the hydrophobic character of the samples. On the other hand, the introduction of oxygenated functional groups (–OH, >C=O, –COOH) onto the rubber surface increases polarity and, therefore, decreases hydrophobicity [16, 17].

Furthermore, a change in hardness after plasma treatment is consistent with a surface hardening mechanism. The surface layer of rubber is chemically modified through chain breaks, micro-crosslinking, surface oxidation, and possibly surface layer compaction, which reduces local deformability and increases hardness. Studies indicate that surface crosslinking (or densification) can occur, increasing the stiffness of the surface layer of some polymers [11, 12].

In the experiment, hardness reached its maximum at 20 000 Hz, indicating that at this frequency, the plasma transferred sufficient energy to promote surface hardening without causing excessive network destruction. At 15 000 Hz (the second-highest hardness), the material removal process was stronger (as evidenced by mass loss), but the hardening process was still underway.

It can be understood that at 20 000 Hz, a stiffer surface layer was generated (higher density of crosslinks, greater surface oxidation), resulting in greater hardness [11, 12]. At lower frequencies, the effect was less pronounced. At very high frequencies, damage or degradation could occur, inhibiting an increase in hardness.

Similarly, changes generated on the rubber surface by low-pressure air plasma, through the formation of oxygenated functional groups (carbonyls, hydroxyls, and peroxides), increase the material's Young's modulus, resulting in greater stiffness at intermediate frequencies [16]. On the other hand, when the plasma frequency is excessive, surface degradation or the removal of functional groups can be triggered [14].

In general, a nonlinear behaviour is observed for the various quantified variables, highlighting the sensitivity of butyl rubber to plasma treatment conditions and the importance of optimising parameters such as frequency. Intermediate frequencies, such as those near 20 000 Hz, appear to offer an optimal balance between treatment intensity and preservation of the polymer's surface integrity [15, 16]. This behaviour reflects what has been reported in the literature. Plasma modification initially produces an increase in polarisation and roughness (improving wettability) [17]. Subsequently, with further exposure, surface hardening (crosslinking) occurs, increasing hardness and reducing elasticity. Finally, excessive treatment can generate surface damage or microcracks in the surface layer, which may restore some elasticity or promote other mechanisms [12,13].


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## CONCLUSION

Pulsed air plasma treatment at low pressure modified the surface properties of interest in butyl rubber as a function of the plasma generation frequency. The observed behaviours (maximum mass loss and lower hydrophobicity at 15 000 Hz, greater hardness at 20 000 Hz, and greater elasticity at 10 000 and 30 000 Hz) are related to surface modification mechanisms of the rubber, including material degradation, functionalisation with polar groups, surface hardening (crosslinking), and damage or weakening of the surface layer under extreme regimes. The plasma frequency is a fundamental variable that can indirectly reflect the energy and ionisation density of the system; therefore, modifying it reveals the predominance of different interaction mechanisms. Adjusting the plasma characteristics (frequency, exposure time, and generation pressure) can modify the surface properties of samples of interest, as needed for their practical applications.

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## REFERENCES

[1] S. Ebnesajjad y A. H. Landrock, “Classification of adhesives and compounds,” en Adhesives Technology Handbook, 3rd ed. Amsterdam, Netherlands: Elsevier, 2015, pp. 67–83, doi: 10.1016/B978-0-323-35595-7.00004-8.

[2] Chembroad, “Caucho sintético butílico: propiedades, usos y aplicaciones,” 2024. [En línea]. Disponible:https://www.chembroad.com/es/butyl-synthetic-rubber-properties-uses-and-applications/ [Consultado: 28-oct-2025].

[3] L. Benyahia, M. Ji y F. Poncin-Epaillard, “Mechanical behaviour of plasma-treated metal-rubber assemblies,” Molecules, vol. 29, no. 23, p. 5590, 2024, doi: 10.3390/molecules29235590.

[4] J. Tyczkowski, J. Balcerzak, J. Sielski y I. Krawczyk-Kłys, “Effect of carbon black nanofiller on adhesion properties of SBS rubber surfaces treated by low-pressure plasma,” Polymers, vol. 12, no. 3, p. 616, 2020, doi: 10.3390/polym12030616.

[5] G. Primc y M. Mozetič, “Surface modification of polymers by plasma treatment for appropriate adhesion of coatings,” Materials, vol. 17, no. 7, p. 1494, 2024, doi: 10.3390/ma17071494.

[6] M. A. Martínez, J. Abenojar y D. García-Pozuelo, “Effect of plasma treatment on coating adhesion and tensile strength in uncoated and coated rubber under aging,” Materials, vol. 18, no. 2, p. 427, 2025, doi: 10.3390/ma18020427.

[7] S. Ďurišová, M. Pajtášová, D. Ondrušová, R. Janík, Z. Mičicová y A. Dubec et al., “Effect of low-temperature plasma treatment on rubber properties,” Polimery, vol. 69, no. 4, 2024, doi: 10.14314/polimery.2024.4.5.



Registro ISSN 2448-8186
DOI:10.19136/Jeeos.a10n3.6686

[8] R. Lee, D. Xuan-Nghia, J. Young-Oh y T. Il-Lee, "Adhesion strength enhancement of butyl rubber and aluminium using nanoscale self-assembled monolayers of various silane coupling agents for vibration damping plates," Nanomaterials, vol. 14, no. 18, p. 1480, 2024, doi: 10.3390/nano14181480.

[9] N. Connolly, M. Hysick, D. E. Barlaz, R. Garza, G. Lunardi y D. N. Ruzic, "Characterisation of elastomer degradation in $O_2$/Ar plasma via mass and surface morphology changes," J. Vac. Sci. Technol. A, vol. 42, Art. no. 023004, 2024, doi: 10.1116/6.0003240.

[10] J. Tyczkowski, J. Balcerzak, J. Sielski y I. Krawczyk-Kłys, "Effect of carbon black nanofiller on adhesion properties of SBS rubber surfaces treated by low-pressure plasma," Polymers, vol. 12, no. 3, p. 616, 2020, doi: 10.3390/polym12030616.

[11] J. Tyczkowski, H. Kierzkowska-Pawlak, J. Sielski y I. Krawczyk-Kłys, "Low-temperature plasma modification of styrene-butadiene block copolymer surfaces for improved adhesion: A kinetic approach," Polymers, vol. 12, no. 4, p. 935, 2020, doi: 10.3390/polym12040935.

[12] C. Bai, Z. Gong, L. An, L. Qiang, J. Zhang y G. Yushkov et al., "Adhesion and friction performance of DLC/rubber:The influence of plasma pretreatment," Friction, vol. 9, no. 3, pp. 627–641, 2021, doi: 10.1007/s40544-020-0436-6.

[13] E. Vassallo, M. Aloisio, M. Pedroni,F. Ghezzi, P. Cerruti y R. Donnini,"Effect of low-pressure plasma treatment on the surface wettability of poly (butylene succinate) films,"Coatings, vol. 12, no. 2, p. 220, 2022, doi: 10.3390/coatings12020220.

[14] T. Dufour, "From basics to frontiers: A comprehensive review of plasma-modified and plasma-synthesised polymer films," Polymers, vol. 15, no. 17, p. 3607, 2023, doi: 10.3390/polym15173607.

[15] K. Molnar, B. Józsa, D. Barczikai, E. Krisch, J. E. Puskás y A. Jedlovszky-Hajdu, "Plasma treatment as an effective tool for crosslinking of electrospun fibres," J. Mol. Liq., vol. 303, Art. no. 112628, 2020, doi: 10.1016/j.molliq.2020.112628.

[16] G. Primc y M. Mozetič, "Hydrophobic recovery of plasma-hydrophilised polyethene terephthalate polymers," Polymers, vol. 14, no. 12, p. 2496, 2022, doi: 10.3390/polym14122496.

[17] P. Pongsopa, K. Honglertkongsakul y P. Homhuan, "Surface modification on vulcanised rubber by DBD plasma," Adv. Mater. Res., vol. 1119, pp. 375–378, 2015, doi: 10.4028/www.scientific.net/AMR.1119.375.



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