

RESEARCH PAPER

Effect of Chlorophyll and TiO₂ Nanoparticles on the Mechanical Properties of Silicone Rubber

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ABSTRACT

After extracting chlorophyll from celery plant and leaves and antioxidant, we took 100 grams of SIR rubber and added chlorophyll at different ratios (10, 20, 30, and 40) pp/hr. The effect of this addition on the mechanical properties of the prepared composite rubber was then investigated. The results showed a decrease in tensile modulus, elastic modulus, and stiffness, along with an increase in elongation. The optimal ratio was 20 pp/hr. FTIR spectroscopy results for the rubber and chlorophyll indicated that the material was composite, and no new peaks appeared on the silicone rubber. The silicone rubber (SIR + CII) was then reinforced with fine-particle titanium dioxide (TiO₂) powder at different ratios (10, 20, 30, 40) pp/hr. The effect of titanium dioxide on the mechanical properties was also investigated at these different ratios. The tensile modulus, elastic modulus, and stiffness increased, while the elongation decreased. The X-ray penetration resistance of the silicone rubber sample with titanium dioxide was measured at a concentration of 20 pp/hr, resulting in the titanium dioxide imparting a white color to the silicone rubber.

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INTRODUCTION

Experimental evidence suggests that chlorophyll protects against ionizing radiation in test animals. Preliminary reports indicated that chlorophyll significantly reduced the mortality rate of mice exposed to high doses of X-rays. In 1962, Dues Calloway and colleagues administered lethal doses of radiation to guinea pigs fed a nutrient-rich diet. It was observed that 97% of the animals fed chlorophyll-rich vegetables showed no signs of dysfunction, while the remaining animals,

deprived of vegetables, exhibited dysfunction. [1]. As a result of the above, the effect of chlorophyll on radiation, and the purpose of adding chlorophyll to rubber is to protect the rubber chains from the effect of radiation on them, in addition to increasing the resistance of the rubber to radiation, because chlorophyll reduces the effect of radiation on the mechanical properties of rubber, in addition to increasing the protection of the rubber from the effect of radiation on patients [2].

To understand the effect of chlorophyll on the

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mechanical properties of rubber, since chlorophyll is a plasticizing agent when it penetrates between the rubber chains.

Chlorophyll is a pigment found in plant cells, responsible for capturing the high energy of light during photosynthesis, as well as acting as a cofactor in this process. Chemically [3-6], the chlorophyll molecule consists of a Tetrapyrrole (porphyrin) nucleus with a magnesium atom at its center, and a long hydrophobic side chain (phytol tail) attached to a carboxyl group [7-10]. There are five types of chlorophyll molecules in plants, all sharing the same basic structure but differing in the side chain attached to the porphyrin nucleus [11].

The chlorophyll molecule has a high proportion of unsaturated bonds, allowing it to absorb light effectively across both the visible and ultraviolet spectra.

The research problem is that radiation significantly affects the rubber chains in radiation shielding, causing them to break down.

The purpose of adding chlorophyll to the rubber compound, due to its effect on radiation, is to protect the rubber chains from breaking down caused by radiation and the resulting heat conversion within the material. Additionally, it increases the rubber compound's resistance to radiation because chlorophyll reduces the impact of radiation on the rubber's mechanical properties, thus enhancing the compound's protection against

radiation exposure in patients.

MATERIALS AND METHODS

Preparing chlorophyll and mixing it with rubber (silicone rubber), and methods for examining it using optical methods. Ratios of (10,20,30,40) pphr were added, and the best ratio was 20 pphr. Titanium was added in different ratios, (10, 20, 30, 40) pphr, and the optimal ratio for titanium was 20 pphr. (Chlorophyll Pigment Extraction)

1) Wash and dry the celery leaves, 2) Chop the celery leaves and place them in an acetone solution, 3) Strain the mixture using a fine-mesh cloth, 4) Store the extracted pigment solution in an airtight container, 5) Place the resulting solution in an oven at 40°C to evaporate the acetone.

Due to its high electron pairing (reflected in the presence of numerous double bonds within the chlorophyll molecule), chlorophyll absorbs a wide range of wavelengths in the visible, ultraviolet, and ionizing spectra. The energy of the absorbed photon transfers the chlorophyll from its stable ground state to an excited state. This excited state can then transition to a less excited state or return to its ground state.

The remaining energy is randomly transferred to other chlorophyll molecules and then to the pigment reaction center. Thanks to their positions and energies in the excited state, chlorophyll molecules can donate electrons, making them oxidized [12, 13].



A B
Fig. 1. A - Manual cutter for cutting samples. B – Test samples after cutting.

Chlorophyll was added to the rubber compound at ratios of 10, 20, 30, and 40 pphr, with 20 pphr being the optimal ratio based on mechanical testing. Its mechanical properties and radiation permeability were studied. This material's ability to absorb electromagnetic radiation and its antioxidant properties help protect the resulting rubber compound from radioactive decay [14, 15]. Then, titanium oxide (TiO_2 , 40) pphr (10, 20, 30) was added to the main mixture (100 pphr silicone rubber + 20 pphr chlorophyll), and its mechanical properties were studied, and its radiation permeability was calculated, after which 20 pphr was chosen as having the best results [16, 17].

Tensile Testing Instrument:

In the current study, tensile properties were measured using a device type (Monsanto T10

Tansometer Equipment). This device is controlled by a microprocessor with a plotter and a pneumatic sample holder system. It is designed to test tensile strength, modulus of elasticity, and elongation percentage at cut in accordance with ASTM D-412-88. Before the inspection process, the dimensions of the sample (thickness and width) are entered into the device's memory [18]. This helps to obtain the required elongation and stress, which is recorded by the device shown in Fig. 1. The movement of one of the jaws is upward and at a speed of (50 mm/min) while the other jaw is fixed. Using the plotter, we obtain a (stress-strain) curve.

The tensile, elastic, and elongation properties were measured using the device shown in Fig. 2.

Hardness Test Instrument

The Hardness Test is based on measuring the



Fig. 2. A measuring device for examining tensile properties, modulus of elasticity, and elongation.



Fig. 3. Mold for producing hardness test samples.

penetration of a hard ball into a rubber sample under standard conditions using the Shore a method. As the force is applied by means of the static load (Dead Load), a mechanical structure is used to apply the secondary force (contact force) or the main force on the notch. The means of measurement is a simple (Dial Gauge) listed on the Shore A scale to measure the hardness caused by the main load, and the examination is carried out in accordance with the specification (ASTM D-1415). The hardness measurement samples were prepared using the molds shown in Fig. 3. and Fig. 4 shows a hardness measuring device.

RESULTS AND DISCUSSION

Tensile Strength and Elastic Modulus of Elasticity

From Figs. 5 and 6, we observe a decrease in

the tensile strength and modulus of elasticity. This is attributed to the use of acetone as a solvent in the extraction of the green pigment. Some acetone remains mixed with the elastic paste before evaporating, leading to a separation of the polymer chains. This separation reduces both the tensile strength and stiffness. Furthermore, chlorophyll acts as a plasticizer, further reducing tensile strength and stiffness while increasing elongation [19].

To study the effect of chlorophyll on the mechanical properties of rubber composite, a chlorophyll concentration of 20 pphr was selected as the optimal ratio and used to prepare of rubber composite.

From Fig. 5 We note that chlorophyll leads to a reduction in tensile strength because chlorophyll



Fig. 4. Hardness measuring device.

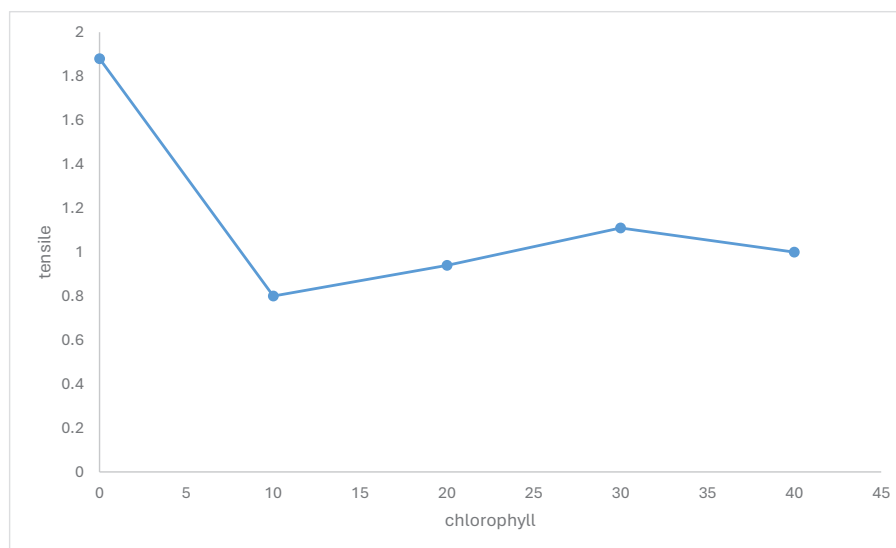


Fig. 5. Tensile strength versus chlorophyll concentration.

is considered a plasticizing substance, which separates the rubber chains. The best ratio is (20) pphr, this is the optimal ratio that allows the rubber material to accept the addition of micro-leads later.

From Fig. 6 We observe that chlorophyll leads to a slight decrease in Elastic modules as a result of the rubber chains binding to the chlorophyll

pigment, a ratio of 20 pphr is the optimal ratio for adding chlorophyll to rubbery dough for the same reason mentioned above in Figure (5).

From Fig. 7 We observe an increase in elongation values with increasing chlorophyll levels. This is because chlorophyll is a plasticizing agent, meaning it creates spacing between the rubber chains, which increases elongation. A ratio

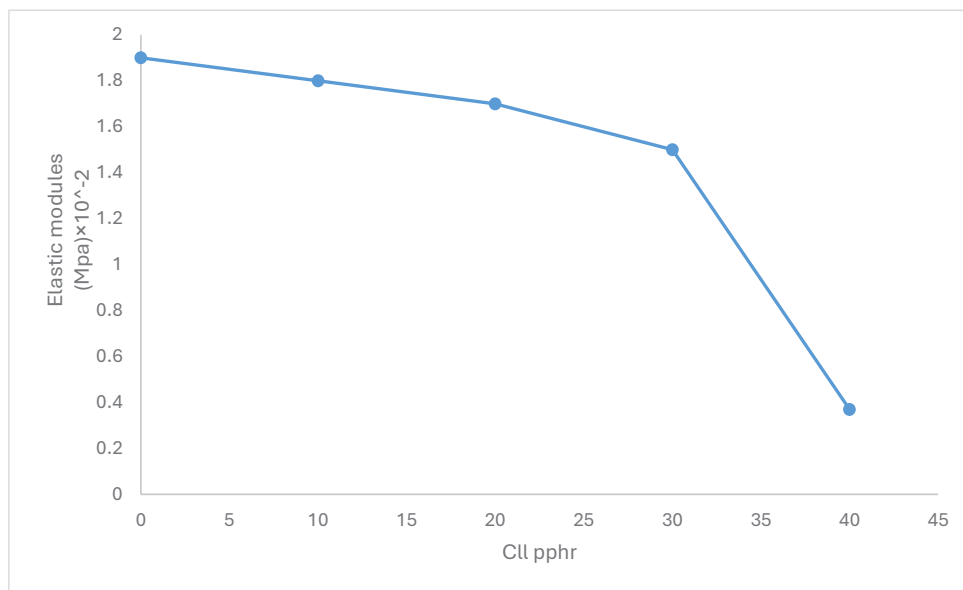


Fig. 6. Elastic modulus versus chlorophyll concentration.

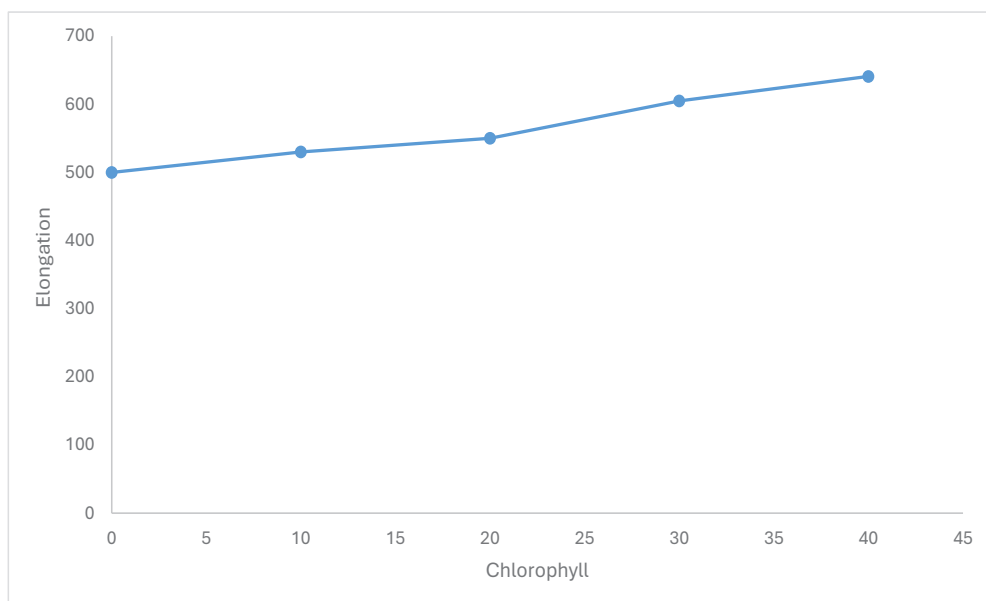


Fig. 7. Elongation versus chlorophyll concentration.

of 20 pphr was chosen as the optimal ratio.

From Fig. 8 We notice a decrease in hardness values with increasing chlorophyll ratios (10, 20, 30, 40) pphr. This is attributed to the fact that chlorophyll separates the rubber chains, as it is a plasticizing substance, the optimal chlorophyll addition ratio is 20 pphr, for the same reason

shown in Figs. 5 and 6.

FTIR property tests for pure silicone rubber

We note that Figs. 9 and 10 are identical, which indicates that the material is pure silicone rubber.

A specific sample was taken and placed in the FTIR device, and we obtained the results as shown

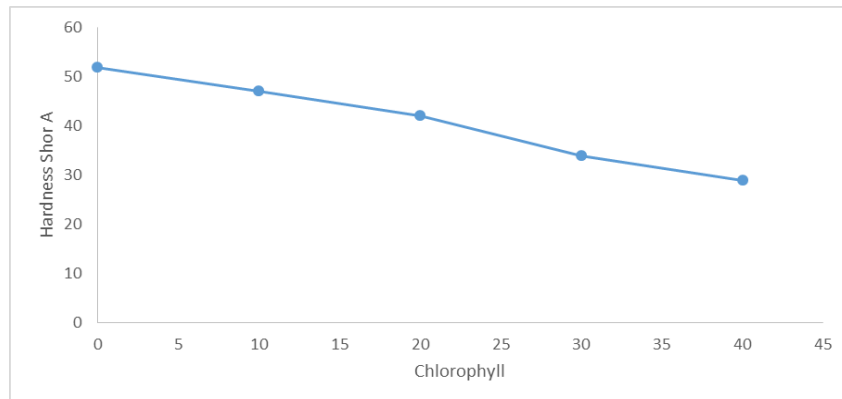


Fig. 8. Hardness versus chlorophyll concentration.

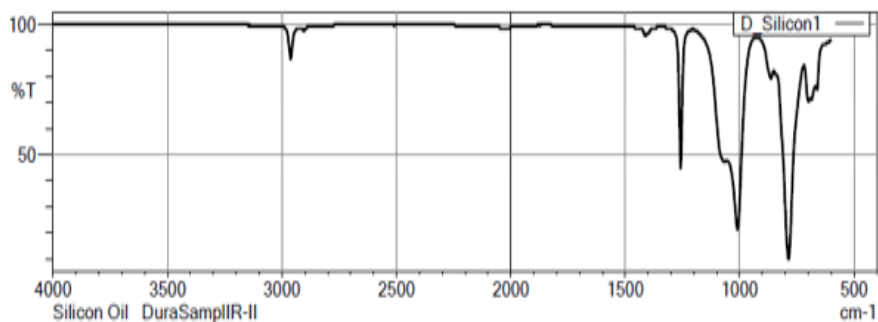


Fig. 9. FTIR chart of pure rubber from the FTIR library.

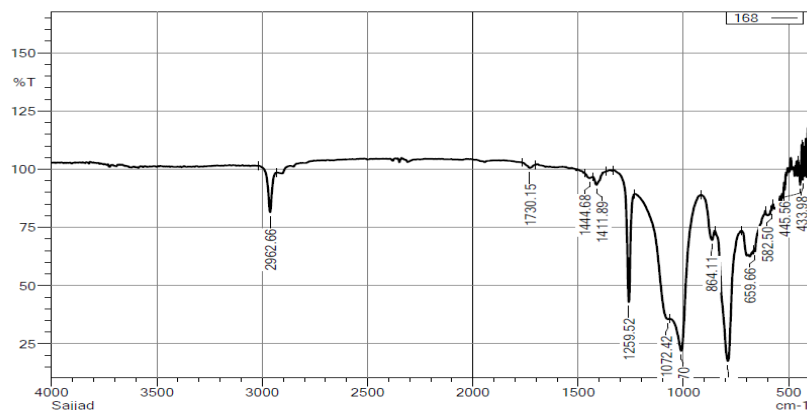


Fig. 10. FTIR chart of the rubber used in the research.

in Fig. 10. After comparing them with Fig. 9, which is the pure sample, it was found that the material present was silicone rubber. This is the same result obtained by [20, 21].

Mechanical property tests for titanium oxide (TiO_2)

The results of the mechanical property tests for mixture (100 pphr silicone rubber + 20 pphr chlorophyll + 20 pphr TiO_2) after the addition of. And Figs. 11 and 12, there is an increase in tensile strength and modulus of elasticity with increasing weight percentages of the filler (TiO_2). These

results are attributed to several factors, most importantly the increased cross-linking between the rubber chains and the filler, and the particle size, which is characterized by a large surface area. Additionally, the irregular particle shape, containing irregularities, contributes to increasing the surface area and the interlocking between the rubber chains and the filler.

From Fig. 11 We observe an increase in tensile strength with concentrations of 10, 20, 30, and 40 pphr. This is due to the action of the granules on bonding the rubber chains through a process

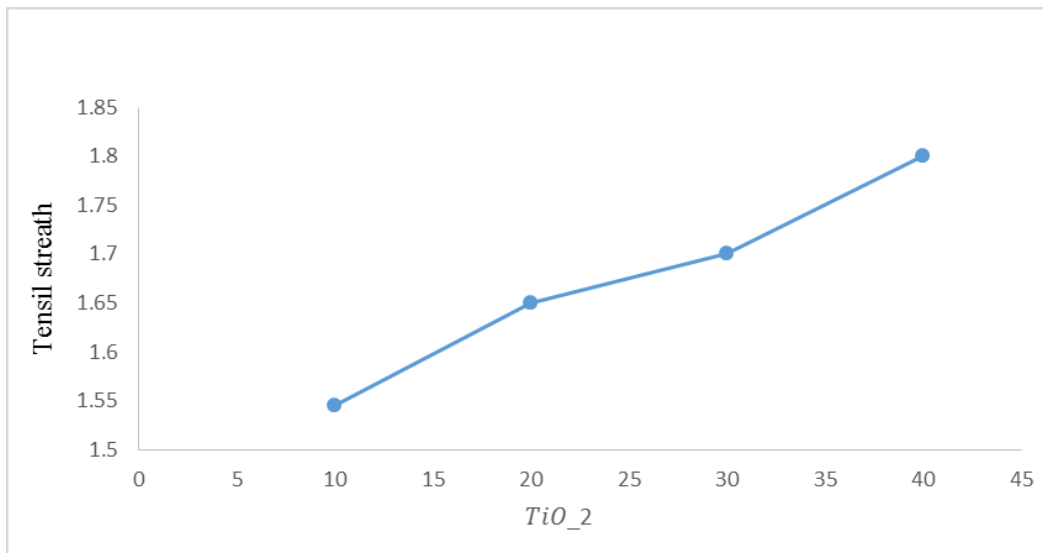


Fig. 11. Tensile versus concentration. TiO_2

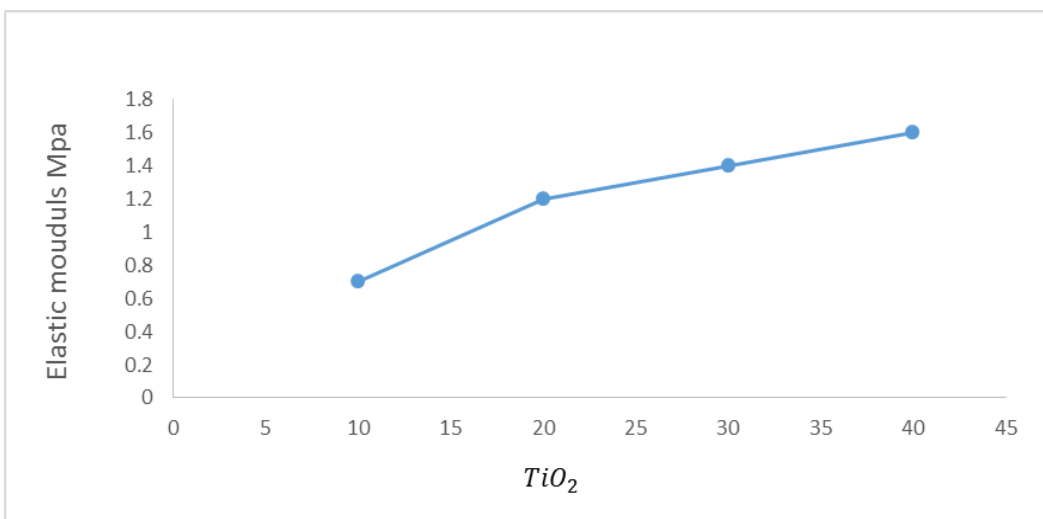


Fig. 12. Elastic modulus versus concentration.

called Bessemerization. The optimal concentration is 20 pphr, which allows the addition of micro-lead powder to silicone rubber material.

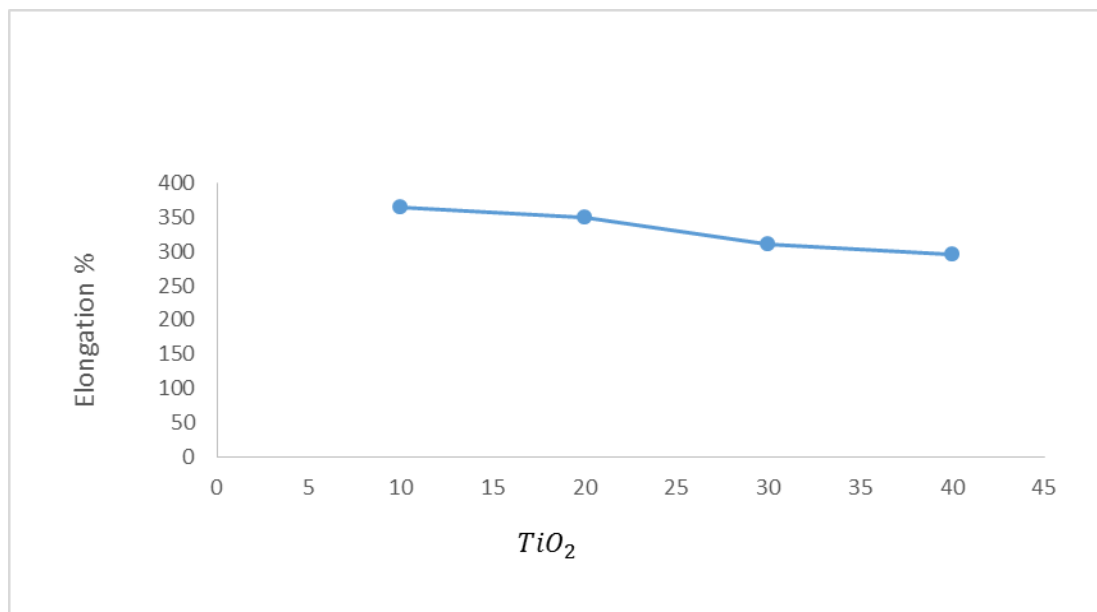
From Fig. 12, we observe an increase in the modulus of elasticity values with the TiO_2 ratios, for the same reason mentioned above in Fig. 11.

From Fig. 13 We observe a decrease in elongation rates with increasing TiO_2 , and a value of 20 pphr is optimal.

From Fig. 14 We notice an increase in hardness values with TiO_2 ratios due to the bonding process between the rubber chains, The optimal ratio is 20 pphr, for the same reason mentioned above in Fig. 11.

Results of FESEM properties tests of silicone rubber

SEM images of prepared silicon rubber were presented at two magnifications in Figs. 15 and 16.



From figure 13 We observe a decrease in elongation rates with increasing TiO_2 , and a value of 20 pphr is optimal.

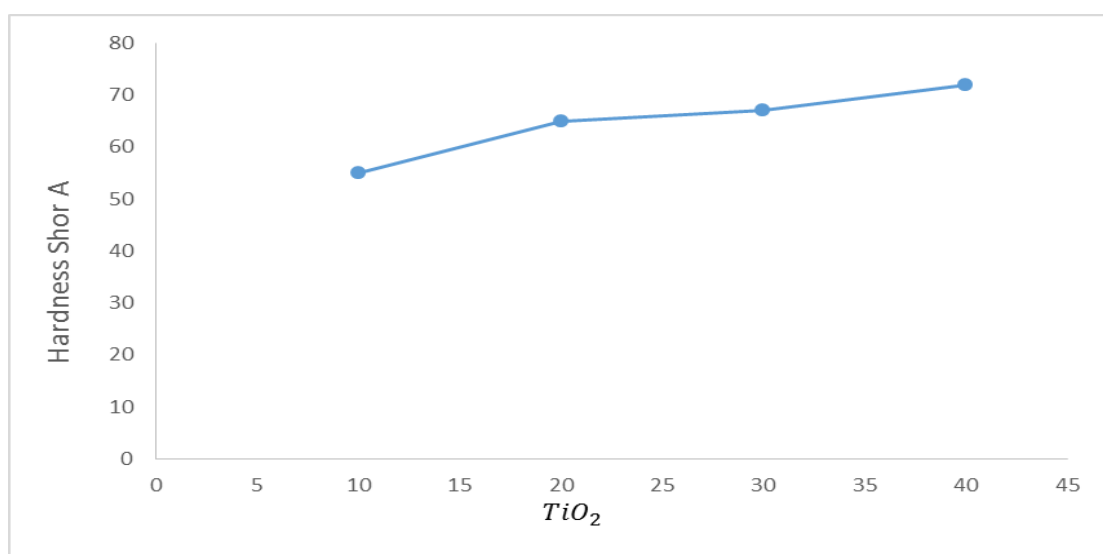


Fig. 14. Hardness versus concentration.

XRD test results

We notice from Fig. 17 the presence of peaks of (10-15) 2θ and (28, 30, 48, 50, 52, 58) 2θ that belong to chlorophyll, silicone rubber, and titanium (TiO_2).

We notice from Fig. 18 at the angle (10-25) 2θ the presence of nano-lead, as well as at the angle (28-30) 2θ , as well as at the angle (32, 36, 48, 55, 58, 62, 78) 2θ , which belong to micro lead.

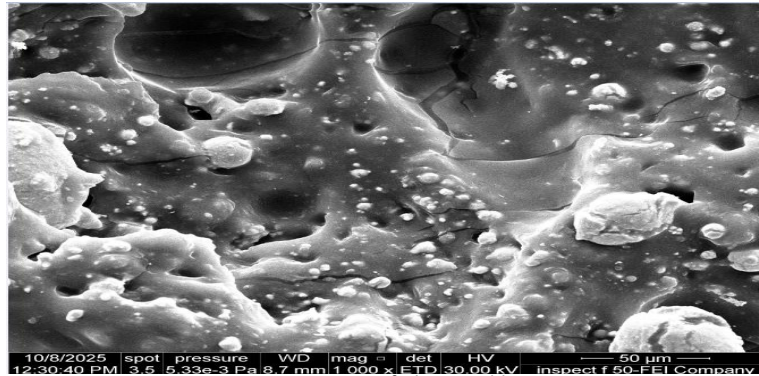


Fig. 15. Microscopic examination of silicone rubber measuring 50µm.

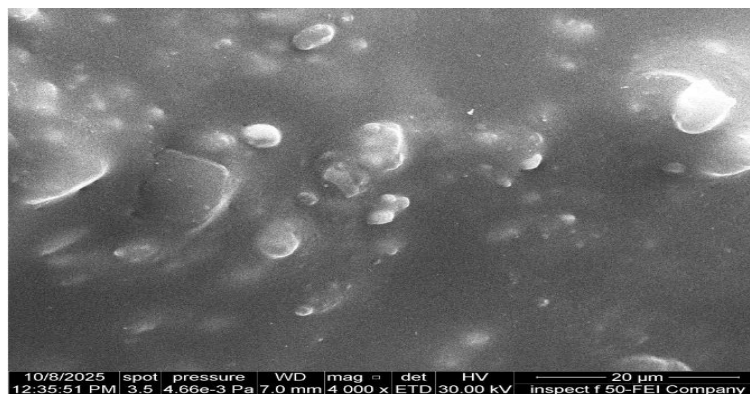


Fig. 16. Microscopic examination of silicone rubber measuring 20µm.

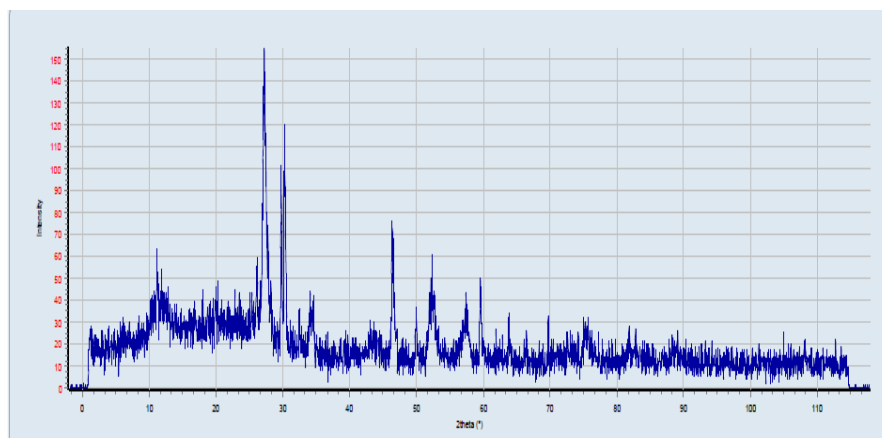


Fig. 17. represents the XRD results for silicone rubber paste, chlorophyll and titanium (TiO_2).

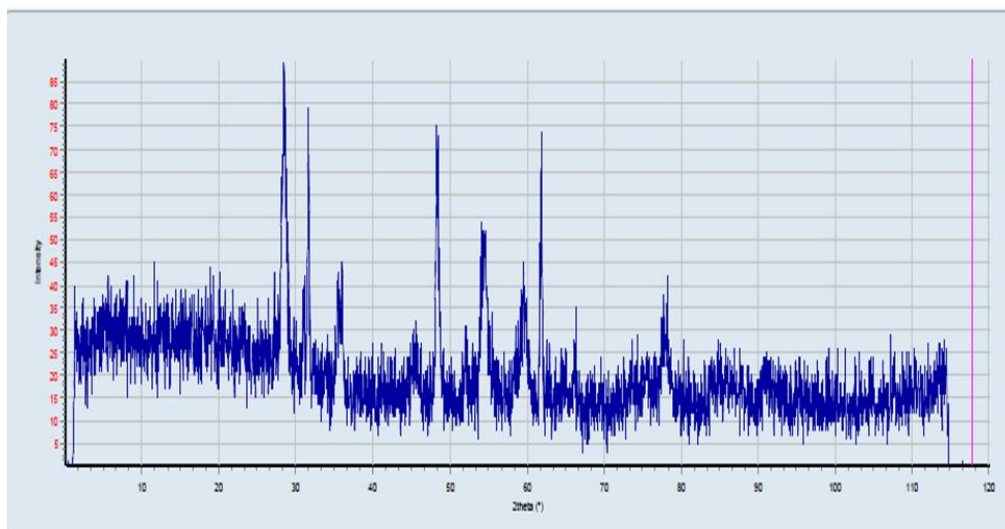


Fig. 18. represents the XRD results for micro and nano lead results.

CONCLUSION

Several ratios of chlorophyll were added to the silicone rubber paste (10, 20, 30, and 40), with 20 pphr being the optimal ratio, providing a balance in mechanical properties suitable for future lead addition. Several ratios of TiO_2 were also added to the silicone rubber paste (10, 20, 30, and 40), with 20 pphr being the optimal ratio, to allow for the later addition of micro-lead. FTIR analysis revealed that the material is a physical composite due to the absence of new peaks. We recommend adding micro-lead to the composite rubber paste (silicone rubber) to enhance radiation absorption.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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