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EFFECT OF CALCIUM CARBONATE CONTENT ON THE SURFACE VOLTAGE GENERATED BY ROCKS

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ABSTRACT

When two materials come into contact with one another, it is known that charges could be transferred from one surface to the other. This phenomenon is known as the triboelectric effect. The triboelectric series was developed in order to determine the likelihood of charge transfer when two materials come into contact with one another. This study aims to investigate the effect of calcium carbonate content in sedimentary rocks close to the city of Minia on the charge generated on the surface of the rock upon contact with another surface such as Kapton and polymethyl methacrylate (PMMA). The two materials were selected because Kapton is close to the bottom of the series, while PMMA is close to the top.

It was found that a higher calcium carbonate content in a rock made it more likely to obtain a negative charge, thus lowering its position in the triboelectric series. Some rocks which are low in calcium carbonate with a few calcium carbonate-rich pockets on their surface induce a low charge on the surface they touch under a high contact force, due to the easy-to-break calcium carbonate pockets depositing calcium carbonate particles with an opposite charge on the other surface.

KEYWORDS

Triboelectric effect, calcium carbonate, rocks, triboelectric series.

INTRODUCTION

For thousands of years, it has been quite well known that if two materials come into contact, they can sometimes be charged and an electrical charge can occur between them. In modern times, this phenomenon has been named as the triboelectric effect, [1 - 3]. This effect has been used in multiple applications from the Van de Graff generator, [4], to the Triboelectric Nanogenerator, [5 - 10]. The cause of the triboelectric effect is still unknown, with ion transfer and electron transfer being likely explanations, [11].

In order to predict the amount and signs of the charges generated from the contact of any two surfaces, the triboelectric series was developed, [12 - 14], where the higher a

material is in the series, the more likely it is to obtain a positive charge when it contacts another material, and the closer it is to the bottom of the series the more likely it is to obtain a negative charge. Mixing two materials that are opposite to each other in the triboelectric series can provide blends that have a lower overall charge generation tendencies, [15, 16]. Polymethyl methacrylate (PMMA) tends to be high in the triboelectric series, while Kapton tends to be lower in the series, [17, 18].

The area around the modern city of Minia has multiple geologic formations, [19]. Most of these formations are composed mostly of sedimentary rocks. Calcium carbonate-rich limestone is especially prevalent in the area and is considered one of the area's most important natural resources. As calcium carbonate has many applications, [20], the percentage of calcium carbonate in samples collected from this area can reach 99.77 % and can be as low as 69 %, [19, 21].

This study investigates the effect of calcium carbonate content in a rock on the surface voltage generated when the rock comes into contact with another surface. This can be helpful in industrial applications that separate minerals using triboelectrification, [22].

EXPERIMENTAL

Three types of rocks were collected from the location at 28°05'33.6"N 30°47'00.9"E near Minia city. One of them had a surface that was entirely white, given the known geology of the region. It is safe to assume that this was because the surface was rich in $CaCO_3$. By immersing that rock in 5 % acidic acid no action occurred. The second rock had a surface that was mostly beige in color with a few white spots, implying that most of the surface of the rock had a low $CaCO_3$ percentage with the exception of some spots with a higher percentage of $CaCO_3$. The third rock had an entirely beige surface, which suggests a lower percentage of $CaCO_3$ on the surface.

At first, the reflected spectrum from a light source by all three rocks was measured by a spectrometer in the visible range. The results are shown in Fig. 4 to Fig. 7. Then the rocks were tested in contact and separation with a Kapton and a PMMA surface under five different contact force values ranging from 2 N to 10 N. The surface voltage on the PMMA and Kapton surfaces was measured after contact-separation by a Surface DC Voltmeter SVM2. The results of this test are shown in Figs. 8 – 10, where each point on the graphs is the average of 10 readings taken at each contact force value.

Fig. 1 Picture from the area the samples were collected from.

Fig. 2 The three rocks, the $CaCO_3$-rich rock (left), the mixed rock (center), and the rock with low $CaCO_3$ content (right).

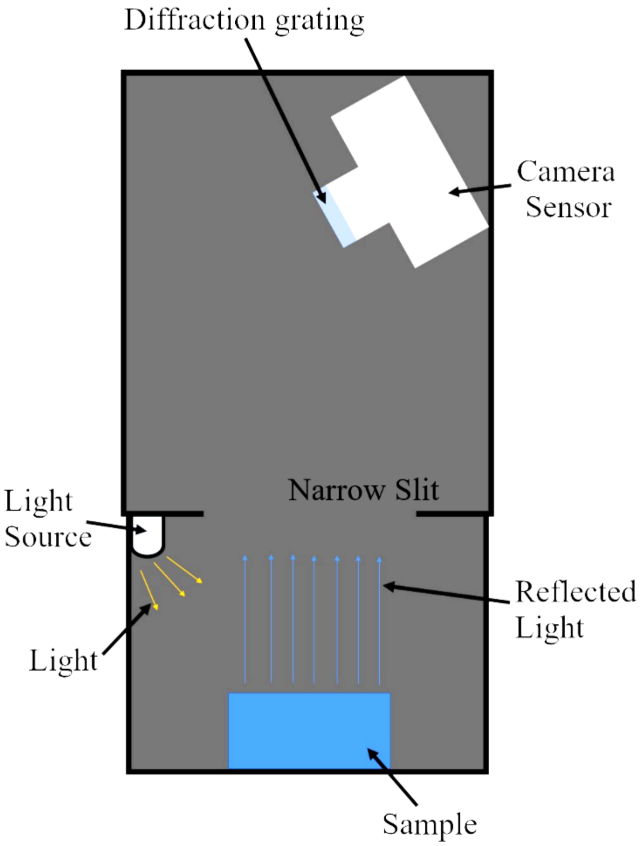

Fig. 3 The Spectroscope used.

RESULTS AND DISCUSSION

It can be seen from Figs. 4, 5 that the reflected spectrum of the $CaCO_3$-rich rock was very similar to the spectrum of the light source as $CaCO_3$ absorbs almost no light in the visible spectrum, [23]. However, some weak absorption lines can be seen as Fig. 5 isn't as smooth as Fig. 4. Figures 6, 7 show that the other two samples show significant absorption of light due to the high percentage of minerals and compounds other than $CaCO_3$, as the shape of the source light is almost entirely gone. The mixed sample's reflected light intensity was higher than that of the sample with low $CaCO_3$ due to the high albedo of $CaCO_3$. Looking at wavelengths with increased reflectance in each figure also reveals some interesting observations, as in both Figs. 5, 6, where a region of high reflectance can be seen in both figures at around 525nm wavelength. This is absent from Fig. 7 implying that this region of high reflectance is characteristic of $CaCO_3$, while a region of increased reflectance can be observed in both Figs. 6, 7 and is absent from Fig. 5 at around 445nm wavelength, implying that it is characteristic of the other compounds present in the mixed and low $CaCO_3$ rocks. Those observations confirms that the mixed sample has a surface that is a mixture of the minerals and compounds found in both the $CaCO_3$-rich rock and the rock with low $CaCO_3$.

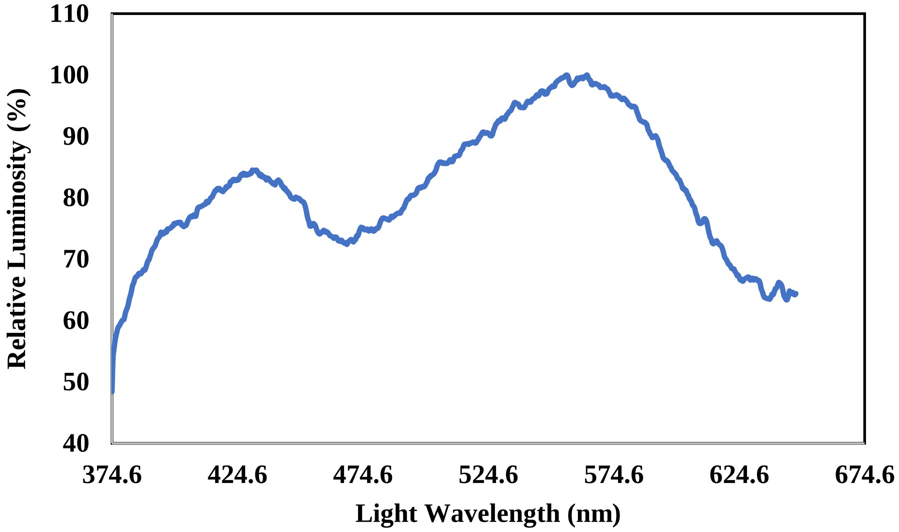

Fig. 4 Source light spectrum.

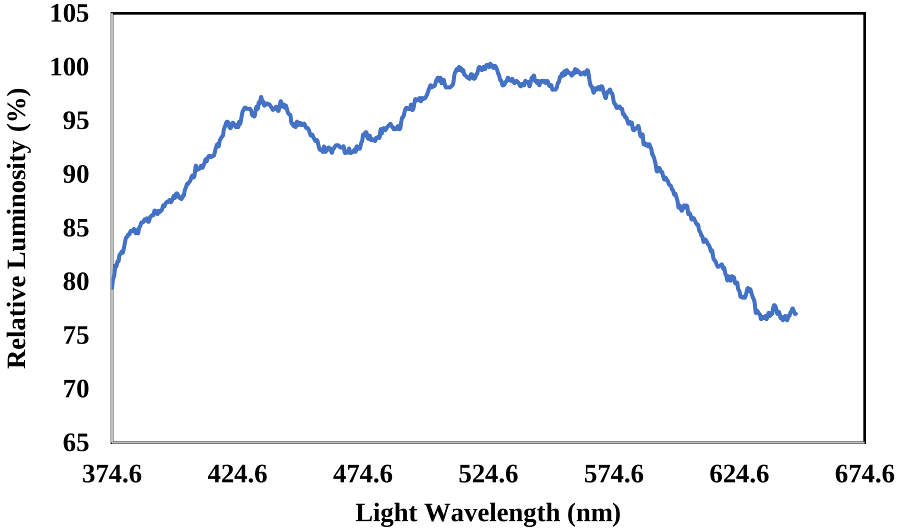

Fig. 5 Reflected spectrum of the $CaCO_3$-rich rock.

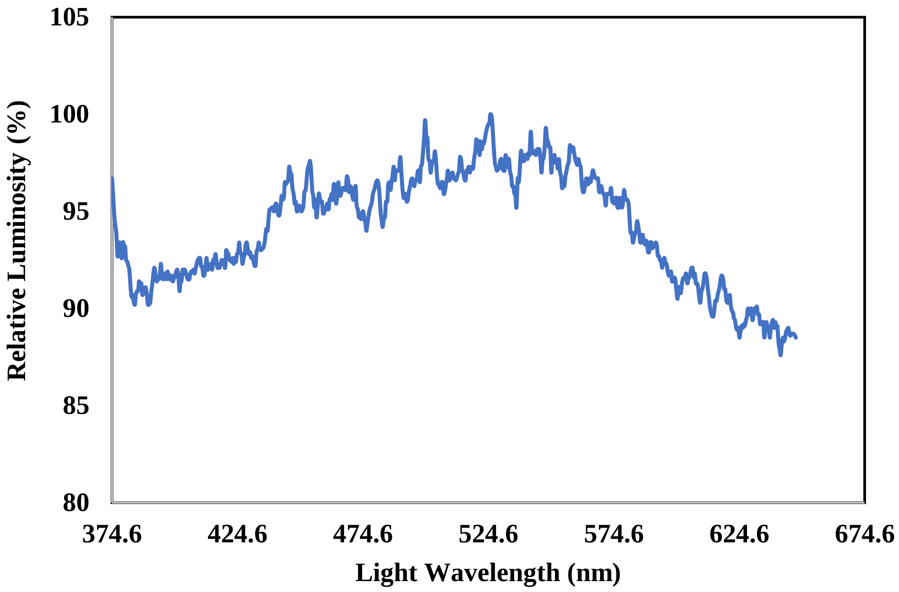

Fig. 6 Reflected spectrum of the mixed rock.

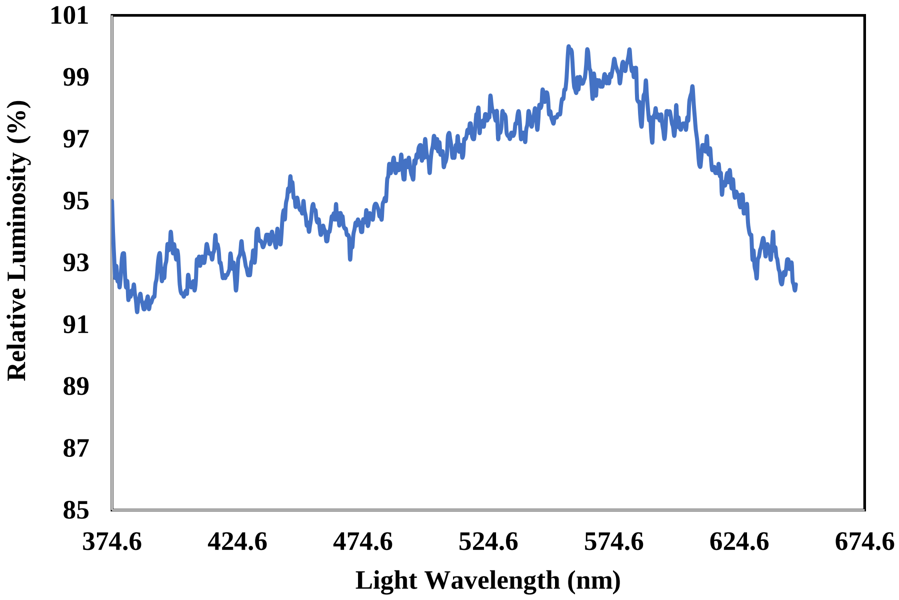

Fig. 7 Reflected spectrum of the low $CaCO_3$ rock.

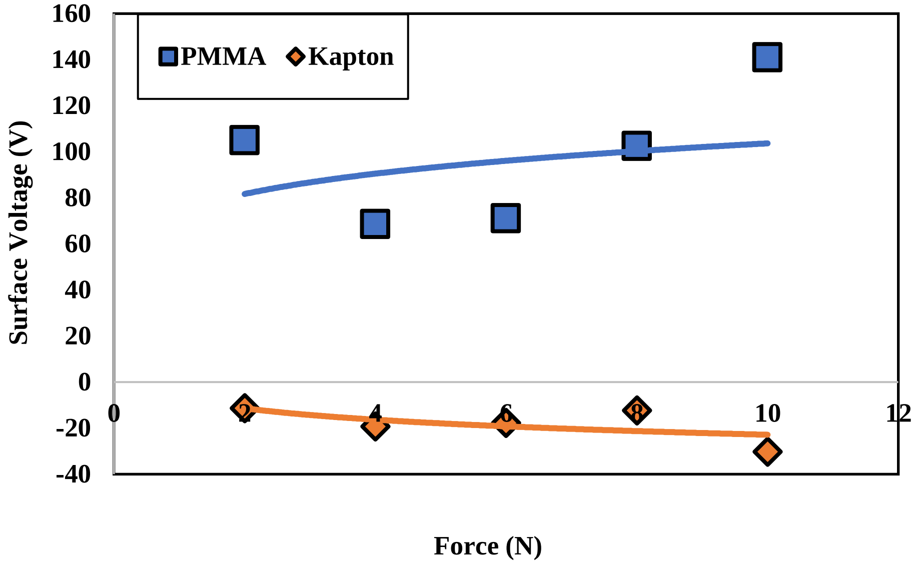

Fig. 8 Surface voltage generated on different surfaces by the CaCO$_3$-rich rock.

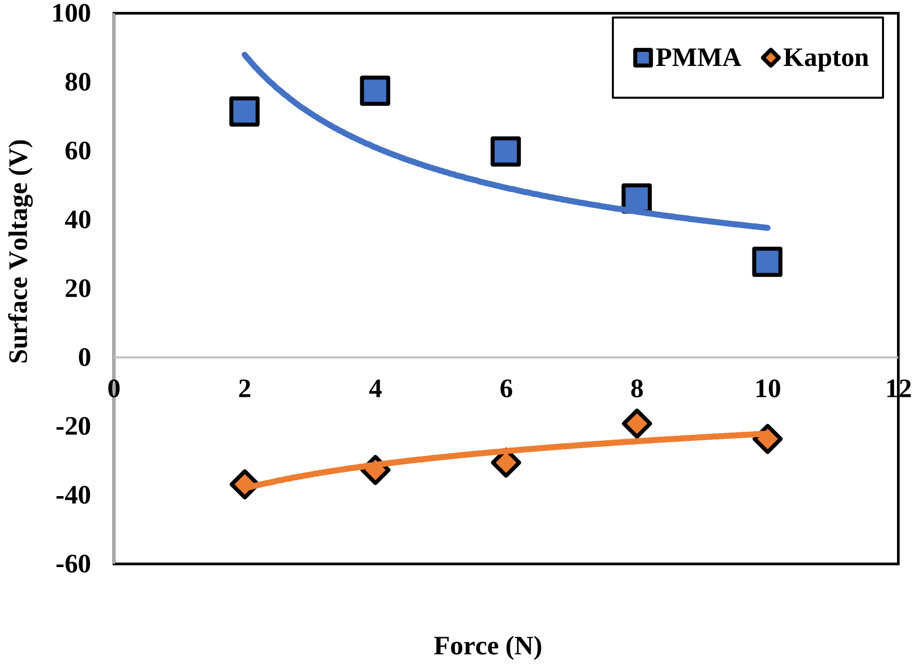

Fig. 9 Surface voltage generated on different surfaces by the mixed rock.

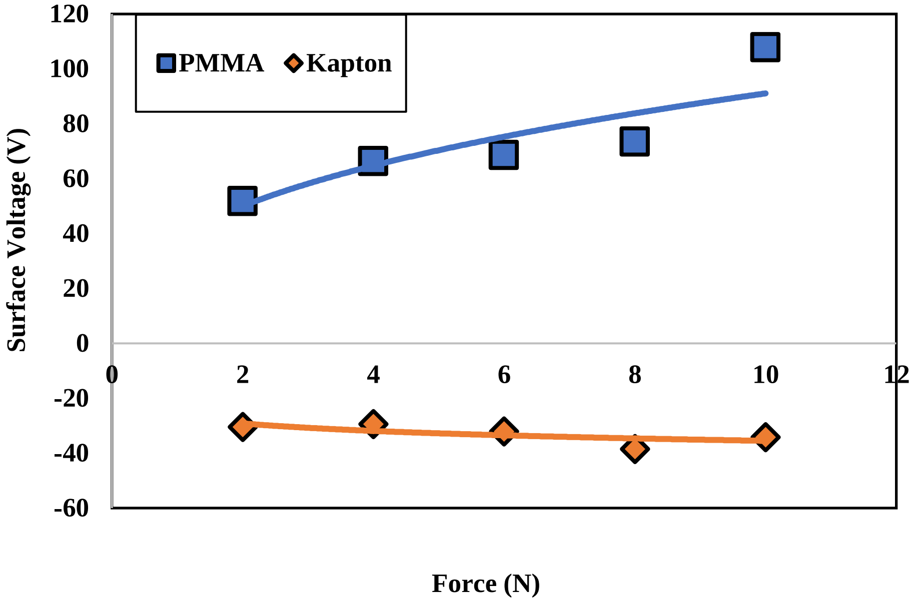

Fig. 10 Surface voltage generated on different surfaces by the low $CaCO_3$ rock.

The voltage generated from contact and separation between the rocks and the Kapton and PMMA surfaces is shown in Figs. 8 - 10, where Fig. 8 shows that the rock rich in $CaCO_3$ generated the highest surface voltage on the PMMA surface at an average of 97.6 volts and the lowest absolute surface voltage on the Kapton surface at negative 18.22 volts. The voltage generated from the mixed rock showed unusual behavior as seen in Fig. 9, where the voltage decreased as the contact force increased. This is probably because of the separation of the $CaCO_3$ particulates from the surface of the rock upon contact (which would be easier in a non-homogenous rock). Since these $CaCO_3$ particles left on the surface would have an opposite charge to the one already present on the surface, the overall surface voltage measured would decrease as more particles of $CaCO_3$ are deposited on the surface. A higher contact force would thus cause a higher number of $CaCO_3$ particles to be deposited on the triboelectrified surface, and thus, the measured surface voltage decreases as the contact force increases.

The voltage generated from contact between the rock with low $CaCO_3$ and the Kapton surface was lower than the voltage generated after contact with the PMMA as shown in Fig. 10. These rocks also have a tendency to be negatively charged, that could be due to the percentage of $CaCO_3$ still being present. However, the voltage generated from the rock with low $CaCO_3$ content was lower than that of the $CaCO_3$-rich rock in the case of contact with PMMA at 73.56 volts and higher than the $CaCO_3$-rich rock in the case of contact with Kapton at negative 32.94 volts. The rock with low $CaCO_3$ content is therefore higher than the $CaCO_3$-rich rock in the triboelectric series. This implies that higher percentage of $CaCO_3$ in a rock causes the rock to be more likely to acquire negative charge when it comes into contact with another surface, therefore, it can be inferred that $CaCO_3$ is low in the triboelectric series.

CONCLUSIONS

1. $CaCO_3$-rich rocks tend to be negatively charged.

2. Sedimentary rocks from the Minia area that have a lower $CaCO_3$ content also tend to be negatively charged, but as much as $CaCO_3$-rich rocks.

3. Rocks with some $CaCO_3$-rich pockets on their surface tend to deposit $CaCO_3$ particles on the surface they contact, decreasing the overall surface voltage on them as the contact force increases.

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