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Analysis of Physical, Thermal, and Structural Properties of Biofield Energy Treated Molybdenum Dioxide

Mahendra Kumar Trivedi[1], Rama Mohan Tallapragada[1], Alice Branton[1], Dahryn Trivedi[1], Gopal Nayak[1], Omprakash Latiyal[2], Snehasis Jana[2, *]

[1]Trivedi Global Inc., Henderson, USA
[2]Trivedi Science Research Laboratory Pvt. Ltd., Bhopal, Madhya Pradesh, India

Email address:
publication@trivedisrl.com (S. Jana)

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Abstract: Molybdenum dioxide (MoO_2) is known for its catalytic activity toward reforming hydrocarbons. The objective of this study was to evaluate the effect of biofield energy treatment on physical, thermal, and structural properties in MoO_2. The MoO_2 powder sample was divided into two parts, one part was remained as untreated, called as control, while the other part was subjected to Mr. Trivedi's biofield energy treatment and called as treated. Both control and treated samples were investigated using X-ray diffraction (XRD), thermogravimetric analysis (TGA), and Fourier transform infrared (FT-IR) spectroscopy. The XRD data exhibited that the biofield treatment has altered the lattice parameters, unit cell volume, density and molecular weight of the treated sample as compared to the control. The TGA study revealed that the onset temperature of thermal degradation of MoO_2 was reduced from 702.87°C to 691.92°C. Besides, the FT-IR spectra exhibited that the absorption band corresponding to Mo=O stretching vibration was shifted to lower wavenumber *i.e.* 975 cm^{-1} (control) to 970 cm^{-1} in treated sample. Hence, above results suggested that biofield energy treatment has altered the physical, thermal, and structural properties in MoO_2 powder. Therefore, the biofield treatment could be applied to modify the catalytic properties of MoO_2 in pharmaceutical industries.

Keywords: Molybdenum Dioxide, Biofield Energy Treatment, X-ray Diffraction, Thermogravimetric Analysis, Fourier Transform Infrared Spectroscopy

1. Introduction

Molybdenum is a well-known element, around 80% is utilized in steel industries to improve the corrosion resistance [1]. The molybdenum compounds have long been use for numerous applications. Molybdenum has oxidation states varying from +2 to +6, among them, oxides exist in two forms *i.e.* molybdenum (IV) and molybdenum (VI) oxide. Molybdenum (IV) oxide (MoO_2) has high electrical conductivity like metals due to presence of delocalized electrons in its valence band [2]. Due to this, MoO_2 is used in rechargeable lithium ion batteries as anode material [3]. In addition, it is also used in solid oxide fuel cell (SOFC) as anode material because it has high fuel flexibility and electrical conductivity [4, 5]. Recently, MoO_2 has gained significant attention due to its catalytic activity towards reforming hydrocarbons. The catalytic action of MoO_2 is governed by metallic site *i.e.* Mo^{+4}. It was reported that the metallic site dissociates the hydrogen (H_2) and produce active hydrogen atoms. After that, the active hydrogen atoms binds with the surface oxygen and form Bronsted acid functional groups [6]. For industrial applications, the physical, thermal, and morphological properties of MoO_2 plays a crucial role. Currently, the physical and thermal properties of MoO_2 are controlled *via* various processes such as reduction of MoO_3 [7], hydrothermal process [8], and thermal evaporation [9], etc. All these process are either require costly equipment setup or high temperature conditions to obtain the desired properties. Thus, it is important to search an alternative approach which can modify the physical and thermal properties of MoO_2 powder.

The energy exists in various forms and there are several ways to transfer the energy from one place to another such as electrochemical, electrical and thermal etc. Similarly, the

human nervous system consists of neurons, which have the ability to transmit information and energy in the form of electrical signals. Due to this, a human has the ability to harness the energy from environment/universe and can transmit it to any object (living or non-living) around the Globe. The object(s) always receive the energy and responded into useful way that is called biofield energy. This process is termed as biofield energy treatment. The National Center for Complementary and Alternative Medicine (NCCAM) has considered the biofield treatment (or healing therapy) under subcategory of energy therapies [10]. Mr. Trivedi's unique biofield energy treatment is known as The Trivedi Effect®. Recently, Mr. Trivedi's biofield energy treatment is known to alter the atomic, physical and thermal characteristics in several metals [11-13] and ceramics [14-16] in material science field. After considering the outstanding consequences with biofield energy treatment on ceramics and metals, this work was designed to evaluate the effect of biofield treatment on the physical, thermal, and structural properties of the MoO_2 using X-ray diffraction (XRD), thermogravimetric analysis (TGA), and Fourier transform infrared (FT-IR) spectroscopy.

2. Materials and Methods

The MoO_2 powder was purchased from Sigma Aldrich, USA. The procured powder was equally divided into two parts. One part was remained untreated, called as control. While, other part was in sealed pack, handed over to Mr. Trivedi for biofield energy treatment under standard laboratory conditions. Mr. Trivedi provided the treatment through his energy transmission process to the treated sample without touching the sample and this part was coded as treated. After that, the control and treated samples were characterized using XRD, TGA, and FT-IR techniques.

2.1. XRD Study

The XRD analysis of control and treated MoO_2 samples was accomplished on Phillips, Holland PW 1710 X-ray diffractometer system. The X-ray of wavelength 1.54056 $\times 10^{-10}$ m was used. From the XRD diffractogram, the peak intensity counts, d value (Å), full width half maximum (FWHM) (θ°), relative intensity (%) values were obtained. The PowderX software was used to compute the lattice parameter and unit cell volume of the control and treated MoO_2 samples. The Scherrer equation was used to compute the crystallite size (D) as following:

$$D = k\lambda/(b\cos\theta)$$

Here, b is full width half maximum (FWHM) of XRD peaks, k=0.94, and λ =1.54056 Å.

The percentage change in crystallite size was calculated using following formula:

$$\% \text{ change in crystallite size} = [(D_t-D_c)/D_c] \times 100$$

Where, D_c and D_t are crystallite size of control and treated powder samples respectively.

2.2. Thermal Analysis

The thermal analysis of MoO_2 powder was done using TGA-DTG. For that, Mettler Toledo simultaneous TGA-DTG instrument was used. The samples were heated from room temperature to 900ºC with a heating rate of 10ºC/min under nitrogen atmosphere.

2.3. FT-IR Spectroscopy

The FT-IR analysis of control and treated MoO_2 samples were carried out on Shimadzu's FT-IR (Japan) with frequency range of 4000-500 cm^{-1}. The analysis was accomplished to evaluate the effect of biofield treatment on dipole moment, force constant and bond strength in chemical structure.

3. Results and Discussion

3.1. XRD Study

The XRD technique is a quantitative and non-destructive technique, which have been widely used to study the crystal structure and its parameters for a given compound. The XRD pattern of control and treated MoO_2 is given in Fig 1. Ths XRD pattern of control sample showed the crystalline peaks at Bragg angle (2θ) 26.02°, 36.97°, 53.51°, 60.25, and 66.67°. The peaks were fitted well with the monoclinic crystal structure according to Joint committee on powder diffraction standards (JCPDS file no. 65-5758 with a space group of P21/c [17]. Furthermore, the treated sample showed the peaks at 2θ 26.04°, 37.00°, 53.55°, 60.29, and 66.68°. It indicated that all XRD peaks were slightly shifted toward higher angles in the treated sample as compared to the control, after biofield energy treatment. In order to study the crystal structure parameters, the PowderX software was used and lattice parameters, unit cell volume, density, and molecular weight were computed. The results are presented in Table 1. The data showed that the lattice parameters "a" and "c" of treated sample were decreased from 5.649 Å (control) to 5.643 Å and 5.650 Å (control) to 5.645 Å, respectively. Also, the reduction in lattice parameters led to decrease the unit cell volume from 13.292×10^{-23} cm^3 (control) to 13.268 $\times10^{-23}$ cm^3. Schwertmann *et al.* reported that the reduction in lattice parameter of unit cell led to shift the XRD peaks toward higher angles [18]. It was also reported that the XRD peaks can shift to the higher side if larger radii atoms are replaced by smaller radii atoms [19]. The decrease in lattice parameter and unit cell volume were supported by shifting of XRD peaks toward higher angles. Thus, based on the shifting of XRD peaks and reduction in the lattice parameters "a" and "c", it is presumed that the biofield treatment might induce compressive stress in treated MoO_2. Due to this, an internal strain might induce in treated MoO_2 after biofield treatment and that possibly resulted in alteration of lattice parameters and unit cell volume.

Nevertheless, the crystallite size was found to be same in control and treated sample as 70.8 nm. Besides, the reduction in unit cell volume caused an increase in density from 6.450 g/cc (control) to 6.462 g/cc in treated sample. On the contrary, the molecular weight of the treated MoO_2 powder was decreased from 129.10 to 128.87g/mol. Hence, the XRD data suggested that biofield energy treatment has altered the physical properties of MoO_2.

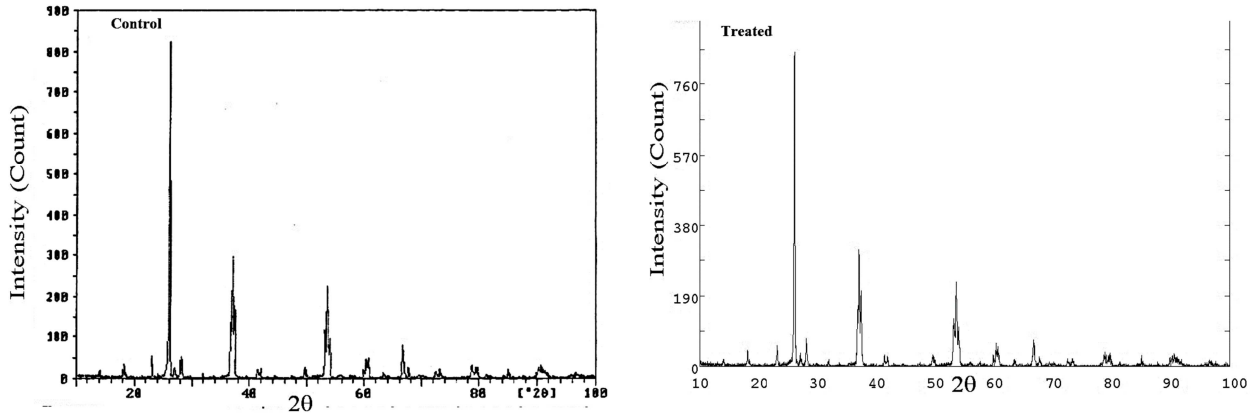

Fig. 1. *X-ray diffractogram of molybdenum dioxide powder.*

Table 1. *X-ray diffraction analysis of molybdenum dioxide powder.*

Group	Lattice parameter "a" (Å)	Lattice parameter "c" (Å)	Unit cell volume ($\times 10^{-23}$ cm^3)	Density (g/cc)	Molecular weight (g/mol)	Crystallite size (nm)
Control	5.6491	5.650	13.292	6.45065	129.10	70.8
Treated	5.6436	5.645	13.268	6.46222	128.87	70.8

3.2. Thermal Analysis

Thermal analysis of MoO_2 was accomplished using TGA-DTG system. The TGA curve of control and treated MoO_2 is shown in Fig 2. The control TGA showed that the sample started to gain the weight around 336.5°C, and continues till 444.5°C. In this process, the weight of control sample was increased by approximately 9.5% as compared to its initial weight. Naouel *et al.* reported that the weight gain by MoO_3 sample in TGA was due to its oxidation [20] Zhang *et al.* reported that the theoretical weight gain during oxidation of MoO_2 to MoO_3 is 12.5% [21].

Nevertheless, the treated sample started to gain the weight at around 386.6 °C and continue to gain till 657.4 °C. In this process the weight of the treated sample was increased by 7.6% with respect to its weight at 306.6°C. It suggested that the onset temperature for oxidation of treated sample was decreased by 8.8% as compared to the control. It could be due to decrease in thermal stability of treated MoO_2 sample after biofield energy treatment. It is assumed that the energy absorbed by the treated sample through biofield energy treatment, probably alter the bond strength of M=O. Due to which, the treated MoO_2 may convert into MoO_3 at lower temperature. Nevertheless, the data also showed that the control sample started to lose its weight at onset temperature 702.87°C and ended at temperature 825°C. The weight loss at this temperature could be due to sublimation of the MoO_3 compound [22,23]. Furthermore, the treated sample showed the onset and endset temperature at 691.92°C and 825°C respectively. The data suggested that the onset temperature of treated sample was reduced as compared to the control. Thus, it is assumed that the intermolecular interaction of the treated sample may get reduced after the biofield treatment and that might be responsible for the reduction of onset temperature in the treated sample as compared to control. Further, the reduction in intermolecular interaction in treated sample may reduce its thermal stability. Besides, the peak width i.*e.* the difference of onset and endset temperature, was calculated as 122.13°C in the control while, it was increased to 133.08 °C in the treated sample. The data also exhibited that in this sublimation process, the control and treated samples were lost around 71.50% and 61.83% of their respective initial weight. Moreover, the rate of weight loss was decreased from 1.50 $\times 10^{-5}$ g/s (control) to 0.88 $\times 10^{-5}$ g/s in treated MoO_2 sample (Table 2). It indicated that the rate of weight loss of treated MoO_2 during decomposition process was decreased by 41.05% as compared to the control. Hence, TGA data suggested that biofield energy treatment has altered the thermal properties of MoO_2.

Table 2. *TGA analysis of molybdenum dioxide powder.*

Parameter	Control	Treated
Peak onset	702.87	691.92
Peak	792.11	790.54
Endset	825.00	825.00
Peak width	122.13	133.08
Percent change in weight at Onset	109.52	105.44
Percent change in weight at endset	38.02	43.61
Change in weight percent	-71.50	-61.83
Percent change in weight/width	-0.585	-0.464
Rate of weight loss ($\times 10^{-5}$ g/s)	-1.506	-0.887
Percent change in rate of weight loss	-	-41.05

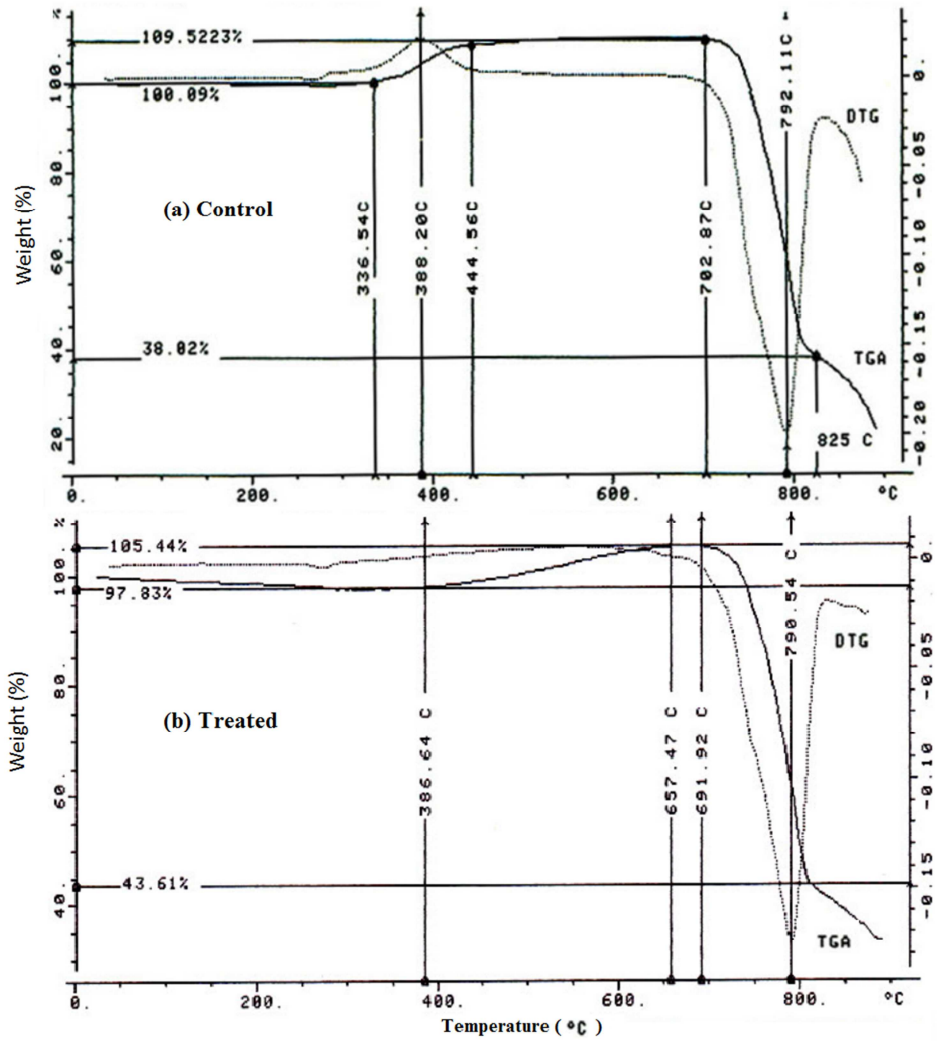

Fig. 2. *TGA thermogram of molybdenum dioxide powder.*

3.3. FT-IR Spectroscopy

The FT-IR spectra of control and treated MoO_2 samples are presented in Fig 3. The control sample showed the absorption band at wavenumber 975 cm^{-1},which was assigned to symmetric stretching modes of the double terminal Mo=O bond [24]. It was shifted to lower wavenumber 970 cm^{-1} in the treated sample after biofield treatment. Previously, our group reported that biofield energy treatment had altered the Ti-O bond length in barium titanate ($BaTiO_3$) [25]. The stretching vibration wavenumber (ν) of a bond is directly related to the bond force constant (k) as follow:

$$v = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}$$

Here, μ is effective mass of atoms, which form the bond.

From the above equation, it can be inferred that the increase of bond force constant leads to increase the wavenumber in FT-IR and *vice versa.* Thus, the decrease in wavenumber corresponding to Mo=O stretching vibration in the treated sample suggested that its bond strength might reduce after biofield energy treatment. In addition, the band observed at 466 cm^{-1} in control, was shifted to lower wavenumber 450 cm^{-1} in the treated sample, which could be due to metal oxygen bond. In addition, the treated sample also showed the absorption bands at 547 and 715 cm^{-1}, which were absent in control sample. It was reported that the band around 715 cm^{-1} is the characteristic peak of the asymmetric stretching vibrations of the O−Mo−O bonds [26]. Based on the above data, it is assumed that biofield energy treatment probably acted at bonding level to cause these modification. Furthermore, the reduction in bond strength in M=O was also supported by the reduction in thermal stability of MoO_2. Besides, in order to use MoO_2 as catalyst in hydrocarbon, it's Mo=O bond strength and thermal stability plays an important role. Hence, the modification of M=O bond strength and thermal stability of MoO_2 through biofield energy treatment could alter its catalytic activities.

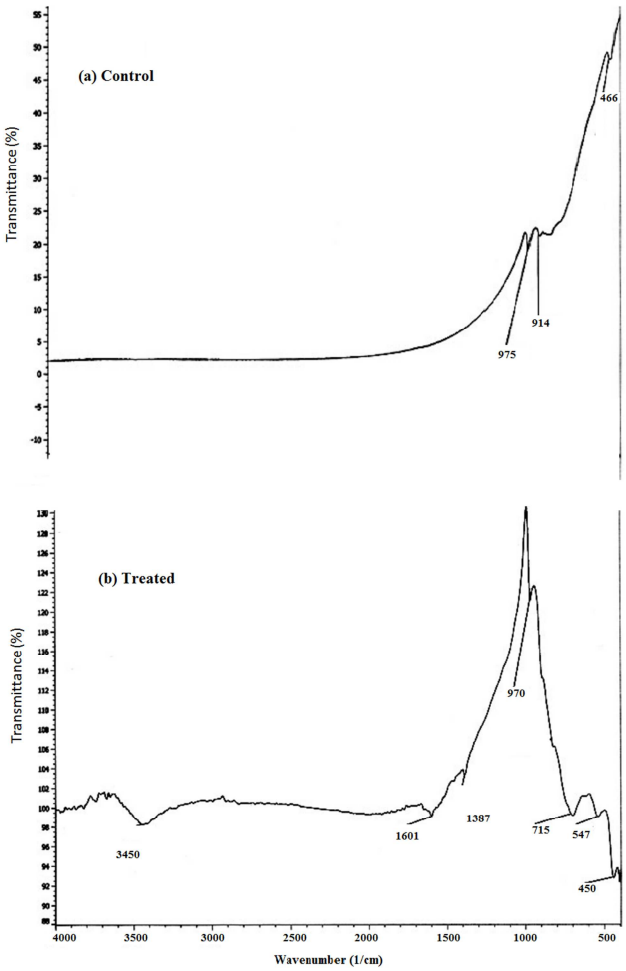

Fig. 3. *FT-IR spectra of molybdenum dioxide powder.*

4. Conclusions

The biofield treatment has reduced the lattice parameters and unit cell volume of monoclinic MoO_2 powder. The XRD data showed the alteration in the lattice parameters, unit cell volume, density and molecular weight of the treated sample as compared to the control. The TGA study revealed that the onset temperature of thermal degradation of MoO_2 was reduced from 702.87 °C to 691.92 °C, which could be due to the reduction of thermal stability of treated sample as compared to the control. The rate of weight loss during degradation in treated sample was reduced by 41.05% as compared to the control. Besides, FT-IR spectra exhibited that the absorption band corresponding to Mo=O stretching vibration was shifted from 975 cm^{-1} (control) to lower wavenumber *i.e.* 970 cm^{-1} in the treated sample, which could be due to reduction of strength of Mo=O bond in the treated sample. Hence, overall data concluded that biofield energy treatment has significant impact on the physical, thermal, and structural properties of MoO_2 powder. Therefore, the modification of thermal stability and bonding strength of treated MoO_2 through biofield energy treatment could make it more useful in catalytic action as compared to the control.

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