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PROCEEDINGS

Editor Dr Milica Vlahović

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FOREWORD

The conditions created by the development of technologies in which modern man lives have led to a complex and paradoxical effect: that by removing obstacles on the way to a more comfortable, simpler, faster and more efficient life and way of working, man also generates numerous misfortunes, attracting dark clouds of threats to the survival of the planet and humanity. The question that concerns and affects all of us - all people, all living beings, systems in which life takes place, large and small, strong and weak - boils down to the problem of the negative impact of man on the environment; this issue invites us to an urgent solution by looking at the causes, proposing solutions, evaluating them, changing approaches and ways of thinking, as well as drawing correct conclusions. Simply put, by adapting nature to one's own needs, man threatens and damages it. That is why, with the joint efforts of all of us, individuals, organizations and states, it is necessary to take all possible measures to immediately prevent the negative effects that are ahead of us.

The importance of renewable sources of electricity, which this international conference focuses on, is noticeable from two angles: the first - it is certain that fossil fuels as a resource will disappear and it is necessary to find alternative sources, the second - the use of renewable energy sources by its essence implies "clean" technology that significantly contributes to reducing CO₂ emissions and thus mitigating climate change and reducing pollution, while encouraging social and economic development in all spheres of life.

The 11th International Conference on Renewable Electrical Power Sources is organized by the Society for Renewable Electrical Power Sources (DOIEE) at SMEITS, with co-organizers: The Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS) and the Chamber of Commerce and Industry of Serbia, with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

The registered participants designed their papers according to the given conference topics:

- Energy sources and energy storage;*
- Energy efficiency in the context of use of renewable energy sources (RES);*
- Environment, sustainability and policy;*
- Applications and services.*

Eminent authors - scientists, teachers, experts in this field from fifteen different countries: Algeria, Belgium, Bosnia and Herzegovina, China, Croatia, Greece, Hungary, India, Portugal, Saudi Arabia, Serbia, Slovenia, Spain, the United Arab Emirates, and Ukraine, contributed to the conference through sixty-nine papers that were reviewed by the Scientific Committee of the Conference, and after the review process were accepted for presentation at the conference and for publication in the proceedings.

At the end of this short message and at the beginning of the proceedings I believe that it can be proudly said that scientists, researchers, policy makers and industry experts gathered in one place, in order to exchange experiences and knowledge with the aim of promoting scientific and professional ideas and results of research, technology improvement for the use of RES, promoting the rational use of electricity, affirming and proposing inventive solutions in the field of sustainable sources of electricity.

*Belgrade,
November 2023*

Milica Vlahović

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SPEKTROSKOPSKA ANALIZA NATRIJUM KARBONATA

SPECTROSCOPY ANALYSIS OF ACTIVATED SODIUM CARBONATE

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Apstrakt

Mehaničko aktiviranje materijala dovodi do kvalitativnih promena u strukturi materijala. Ove promene mogu uključivati akumulaciju energije u vidu slabljenja veza u kristalu, narušavanje kristalne rešetke, aglomeraciju, a u nekim slučajevima čak i sintezu potpuno nove supstance. U ovom istraživanju, anhidrovani natrijum karbonat je mehanički aktiviran 28 minuta u vibro mlinu na frekvenciji od 3000 oscilacija u minuti. Nakon aktivacije, praćene su promene koje se dešavaju u aktiviranom materijalu. Uzorci su stavljeni u atmosferu vazduha u sobnim uslovima 31 dan (period relaksacije). Uočeno je da se tokom perioda relaksacije aktivirani natrijum karbonat apsorbuje vlaga i ugljen-dioksid u obliku hemisorpcije, formirajući natrijum bikarbonat. Mehanizam transformacije je praćen infracrvenom (FTIR) spektroskopijom Furijeove transformacije kao funkcija vremena relaksacije. Praćene su karakteristične grupe: CO_3^{2-} , HCO_3^- i OH^- .

Ključne reči: *Mehanička aktivacija; natrijum karbonat; natrijum bikarbonata; mehanohemijaska transformacija; FTIR.*

Abstract

Mechanical activation of materials leads to qualitative changes in material structure. These changes can include the accumulation of energy in the form of weakening bonds in the crystal, disruption of the crystal lattice, agglomeration, and in some cases even the synthesis of a completely new substance. In this study, anhydrous sodium carbonate was mechanically activated for 28 minutes in a vibro mill at a frequency of 3000 oscillations per minute. After activation, the changes occurring in the activated material were monitored. The samples were placed in the atmosphere of air at room conditions for 31 days (relaxation period). It was observed that during the relaxation period moisture and carbon dioxide were absorbed by the activated sodium carbonate in form of hemisorption, forming sodium bicarbonate. The transformation mechanism was monitored by Fourier-transform infrared (FTIR) spectroscopy as a function of relaxation time. Characteristic groups were monitored: CO_3^{2-} , HCO_3^- and OH^- .

Key words: *Mechanical activation; sodium carbonate; sodium bicarbonate; mechanochemical transformation; FTIR.*

1 Introduction

Sodium carbonate is a compound that responds particularly well to mechanical activation. Namely, its chemical activity significantly increases owing to the weakening of the bonds in the crystal lattice. This enables using sodium carbonate in mechanochemical syntheses which can replace classical chemical processes in extreme operating conditions. Also, its adsorption ability enhances by mechanical activation. It has been observed that activated sodium carbonate, when exposed to the air, adsorbs carbon dioxide and moisture, whereby the amount of adsorbed gases depends on its activation degree (1). This is especially significant because of the increasing emission of carbon dioxide into the atmosphere. Numerous studies reported the attempts to improve the adsorption characteristics of sodium carbonate by various methods in order to adsorb carbon dioxide thus protecting the environment. The results of monitoring the mass change of inactivated and activated sodium carbonate stored for 64 days (relaxation time) in three different media (vacuum, carbon dioxide, and air) at room temperature showed that only the masses of the samples in a vacuum did not change.

The method of mechanical activation, which, in various technical and technological ways, brings mechanical energy to solid materials thus changing and regulating many physico-chemical characteristics related to increasing the system's reactivity, is becoming more and more topical [2-5].

2 Experimental procedure

The sodium carbonate used in this study was anhydrous and in p.a. quality and was mechanically activated in the high-energy mill KHD Humboldt Wedag AG for 28 minutes at a frequency of 3000 r/min. Engine power is 0.8 kW, discontinuously in an air atmosphere, with rings leads to its heating up to a temperature of 80 °C. After activation, the samples were stored at room conditions for 1, 6, 10, 24, and 31 days (relaxation time). The effects of mechanical activation were monitored by FTIR spectroscopy analysis. FFT infrared spectra of the samples were recorded on a spectrometer Bomem-Hartman & Braun Michelson MB-100, in the wave numbers range of 4000-300 cm^{-1} and at a resolution of 2 cm^{-1} . Samples were prepared in the form of a suspension using "Nujol". Changes in the peaks' areas, as well as the widths at the half-heights for groups: CO_3^{2-} , HCO_3^{2-} and OH^- .

3 Results and discussion

The change in the characteristic peaks as a function of relaxation time is clearly noticeable in the diagrams in Figure 1. The initial curves (0 days of relaxation) for all four activation times, at a wavelength of 3500-3600 cm^{-1} , do not have clearly defined peaks, and with the increasing relaxation time. The appearance of the OH group in the activated sodium carbonate sample, as well as changes in the peak area of the OH group, can be explained by the fact that the Na_2CO_3 sample, due to the energy obtained by mechanical activation and disturbed crystal structure had increased adsorption and chemisorption affinity to moisture from the atmosphere during relaxation. The valence OH groups bind to the crystal lattice of activated Na_2CO_3 , and the diagrams show that the peak characterizing the OH group increases with the increasing relaxation time. A similar change is observed at a wavelength of 1645 cm^{-1} , and the database revealed that these changes are also related to the OH group.

At a wavelength of 1420 cm^{-1} , which characterizes Na_2CO_3 , that is CO_3^{2-} ion, a tendency of peak decrease with the increasing relaxation time can be seen. Similar changes are observed at a wavelength of 873 cm^{-1} . This is a consequence of the conversion of carbonate to bicarbonate ion due to the absorption of moisture and carbon dioxide from the air. Parallely with this change, a peak characteristic for the bicarbonate ion at a wavelength of 1800 cm^{-1} appeared. This peak is more pronounced with the increasing relaxation time.

At wavelengths from 2300 to 2400 cm^{-1} , a peak that principally disappears gradually with the progress of relaxation time can be observed. These wavelengths are typical for adsorbed moisture and carbon dioxide. During relaxation, chemisorption of moisture and carbon dioxide occurs and the conversion of carbonate to bicarbonate, which explains the decrease and disappearance of this peak on the observed curves.

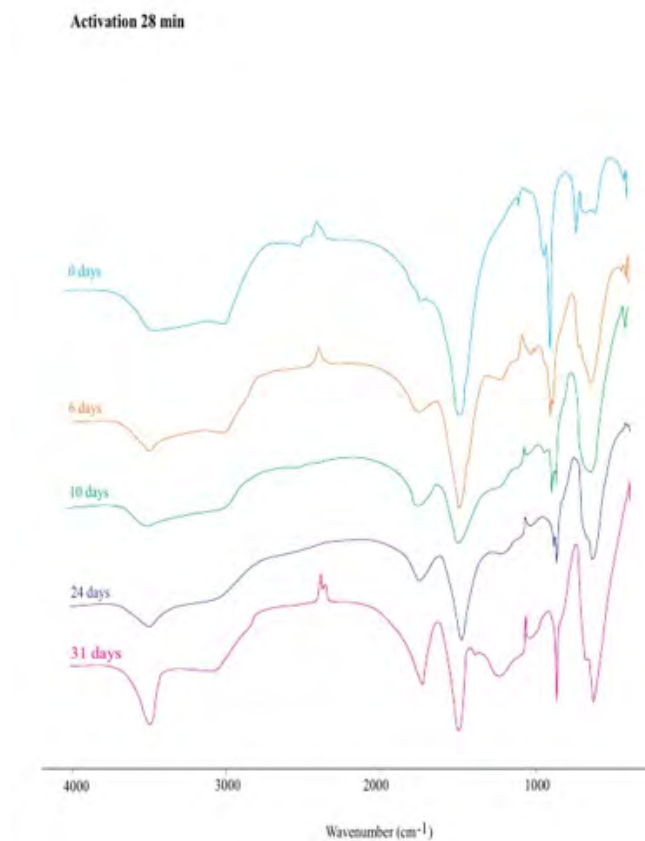


Figure 1. FTIR spectrograms of Na_2CO_3 samples activated for 28 min during relaxation time (0, 1, 6, 10, 24, and 31 days) at room conditions.

The curves shown in Figures 2 show a parallel process of changes occurring on the characteristic groups of activated sodium carbonate and its conversion to bicarbonate as a function of the relaxation time.

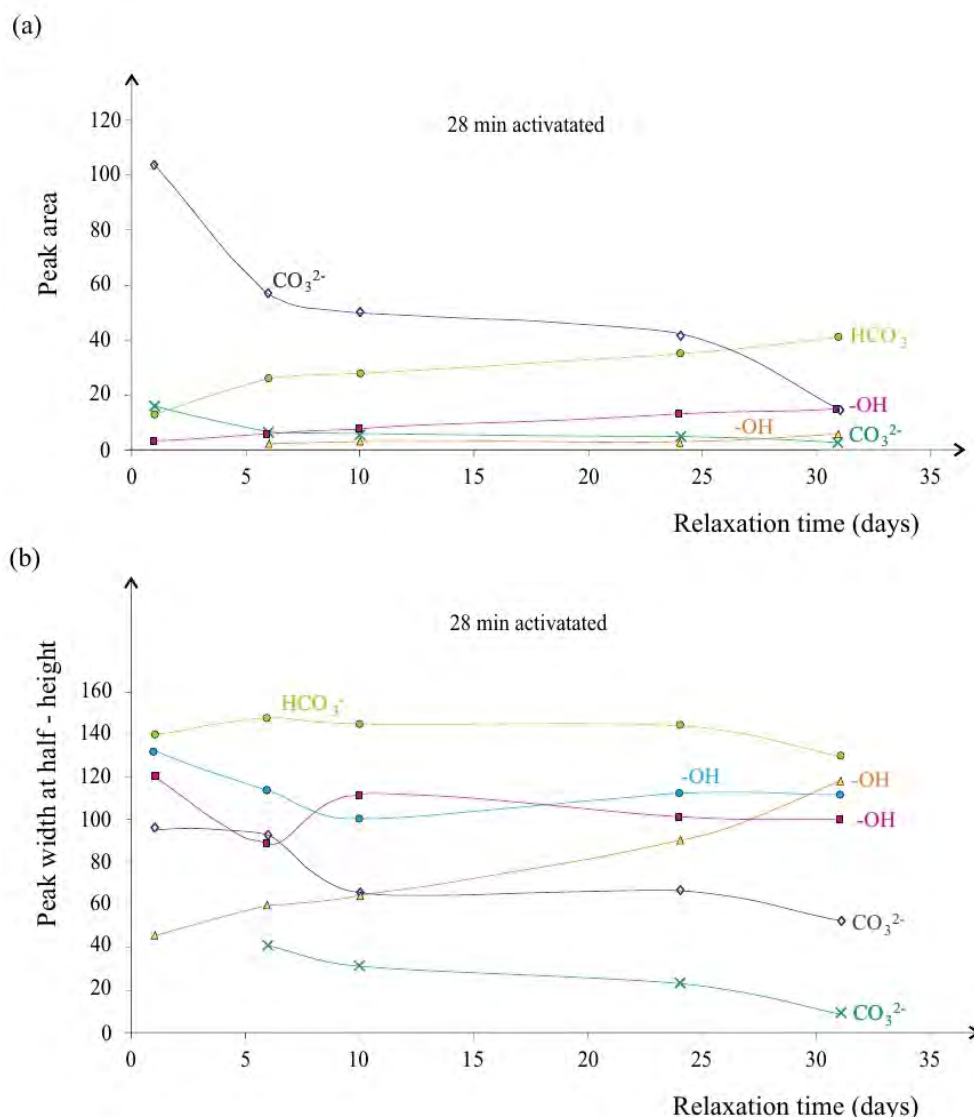


Figure 2 a) Areas of peaks characteristic for ion groups, b) Widths at peak half-height, for Na_2CO_3 sample activated for 28 min as a function of relaxation time.

The peak area characteristic for the CO_3^{2-} ion (Figure 2a) decreases with the relaxation time progress, whereby this drop is sharp during ten days, especially on the first day of the sample aging. The phenomenon can be explained by a significantly enhanced energy of just activated sodium carbonate due to the energy delivered to the system by mechanical activation as well as by the weakened bonds in the crystal. This caused the sudden adsorption of moisture and carbon dioxide from the air as well as the formation of a bicarbonate ion, which is reflected in the increased width of the peak characteristic for the HCO_3^- ion. A similar trend of corresponding width changes at the half-heights of the characteristic peaks can be seen in the diagram shown in Figure 2 b). The reduced width value at the half-height of the peak characteristic for the CO_3^{2-} ion is considerable. The most significant changes for all ions occur in the first 10 days of relaxation time.

4 Conclusions

Although sodium carbonate is a good sorbent, the results showed a gradient of changes in the analyzed samples during relaxation depending on the activation time. The changes in terms of reducing the number of carbonate ions in all four series of samples in favor of the formation of HCO_3^{2-} ions during the relaxation period are clearly noticeable. The key moment in the transformation process is the weakening of the Na–O chemical bond, where during the relaxation time the Na^+ ion was replaced by the H^+ ion, thus forming the OH group. The formation of sodium bicar-

bonate began by bonding the valence OH group to the activated crystal lattice of sodium carbonate. This transformation was taking place after the 25th day of the relaxation period owing to the existence of a sufficient amount of the OH group which directed the reaction towards the bicarbonate formation.

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