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REUSING OF SODIUM SILICATE AS A RAW MATERIAL IN GLASS INDUSTRY: BY-PRODUCT OF SODIUM BOROHYDRIDE PRODUCTION

Aysel Kantürk
Müge Sarı
Özgül Dere
Sabriye Pişkin[1]
[1]Yildiz Technical University, Department of Chemical Engineering, Turkey

ABSTRACT

Global energy and ecology problems continue to grow because of burning of fossil fuels, environmental pollution, decrease of energy sources and difficulties in storing electricity. Hydrogen has great potential to solve these problems as an environmentally clean energy carrier and as a way to reduce reliance on imported energy sources. Hydrogen can be stored and transported safely in the form of sodium borohydride ($NaBH_4$) due to its high theoretical hydrogen yield by weight (10.6%) in applications where H_2 gas is used, e.g., proton exchange membrane (PEM) fuel cells. $NaBH_4$ is synthesized from boron minerals (borax, ulexite, colemanite…) by the thermal-chemical reactions.
The main aim of this paper is the investigation of reusing of Na_2SiO_3, obtained from $NaBH_4$ production based on the conversion reaction of borosilicate glass, as a raw material in glass industry. The by-product, was defined as Na_2SiO_3 (PDF number: 00-016-0818) by XRD (X-Ray Diffractometer) technique, was then vitrificated into a glass for utilization. The obtained glass was characterized by scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) analysis and FT-IR (Fourier Transformer-Infrared spectroscopy) techniques. The results show that by-product Na_2SiO_3 can be reused as a raw material in glass industry.

KEYWORDS

Sodium silicate; Reusing; Vitrification; Sodium borohydride; clean energy.

1 INTRODUCTION

Sodium borohydride ($NaBH_4$), which is known as sodium tetrahydroborate, has attracted attention due to its high theoretical hydrogen content of 10.6 wt % and the excellent stability of its solution under high pH value at ambient temperature [1, 2]. Also, $NaBH_4$ is a selective specialty reducing agent used in the manufacture of pharmaceuticals and other organic compounds [3].
It is important to note that $NaBH_4$ can be produced by economical methods to be applied in practical use. According to the several publications, $NaBH_4$ was synthesized by reacting $NaBO_2$ with MgH_2 or Mg_2Si by annealing the mixture of these two compounds under high hydrogen pressure. Also, it was note that $NaBH_4$ can be produced by reaction of MgH_2 with $Na_2B_4O_7$ through ball milling at room temperature [4, 5].

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In previous study of authors was expressed that process for producing $NaBH_4$, which is based on the conversion reaction of borosilicate glass at temperatures between about 400-500°C under high hydrogen pressure. They defined the by-product as sodium silicate (Na_2SiO_3) [6].

In the present work, reusing of Na_2SiO_3, obtained from $NaBH_4$ production based on the conversion reaction of borosilicate glass, as a raw material in glass industry was investigated. The by-product, characterized as Na_2SiO_3 (PDF number: 00-016-0818) by XRD (X-Ray Diffractometer) technique, was vitrificated into a glass for utilization. The obtained glass was determined by SEM (Scanning Electron Microscopy) with EDS (Energy Dispersive Spectroscopy) analysis and FT-IR (Fourier Transformer-Infrared spectroscopy) techniques. The analysis results indicate that by-product Na_2SiO_3 can be reused as a raw material in glass industry.

2. EXPERIMENTAL

2.1 Material

The by-product (Na_2SiO_3) which was obtained from $NaBH_4$ production is based on the conversion reaction of borosilicate glass at temperatures between about 400-500°C under high hydrogen pressure. The flow chart of $NaBH_4$ production process is given in *Figure 1.*

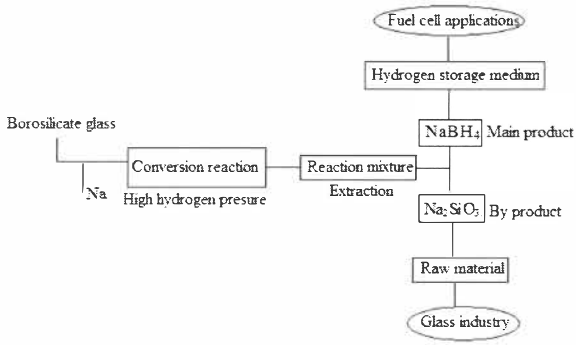


Figure 1. The flow chart of $NaBH_4$ production

After the conversion reaction of borosilicate glass, the resulting reaction product was analyzed by XRD technique for qualitative identification. It was determined that resulting reaction product includes $NaBH_4$ (main product) and Na_2SiO_3 (by product). It was extracted with suitable solution to separate $NaBH_4$ from Na_2SiO_3. Extraction solution was separated from the by product and remaining reactants by filter paper and was evaporated in the rotary dryer. By-product (*see Figure 2*) was dried for two hours before the XRD analysis and XRD pattern is given in *Figure 5.*

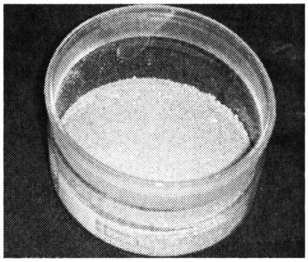


Figure 2. Image of by-product

2.2 Vitrification

In this study, the potentiality of by-product vitrification without any additives was examined for utilizing as a raw material in glass industry. The by-product was subject to a vitrification process to production of glass in a high temperature furnace. The mineralogical structure and the chemical properties of the obtained glass were carried out by SEM-EDS and FT-IR analysis. The images of obtained glass are shown in *Figure 3.*

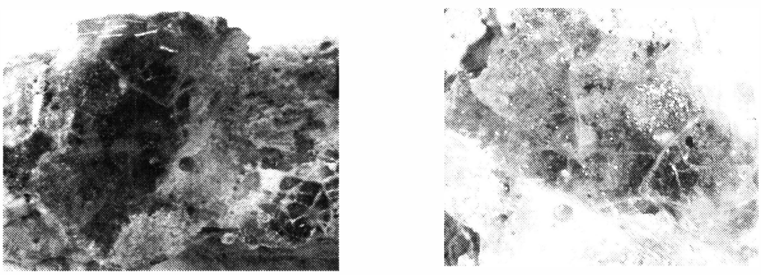
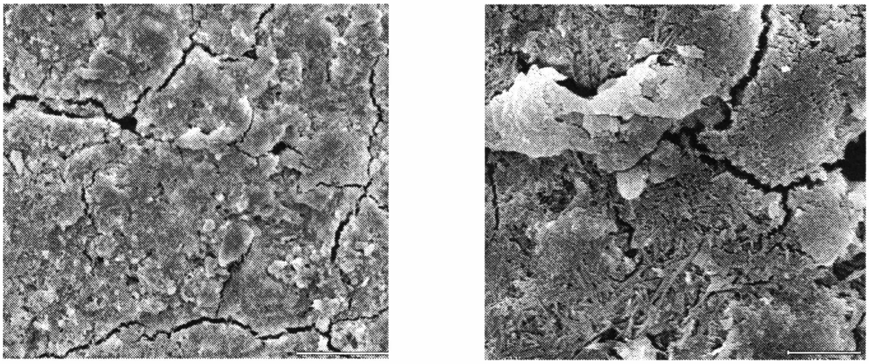


Figure 3. Images of obtained glass after vitrification of by-product

2.2 Characterization

Crystalline structure of by-product obtained by the $NaBH_4$ process was investigated by XRD technique that reveals detailed information about the chemical composition and crystallographic structure of materials. Analysis was made by using a Philips PAnalytical X'Pert Pro diffractometer using CuKα radiation (45 kV and 40 mA) and recorded at room temperature with a diffraction angle from 0° to 90° at 0.02° (2θ) step size. Phase identification was performed using the XRD library available on the data system. XRD pattern of by product is given in *Figure 5.*

Scanning electron microscope (JEOL JSM-5910LV) with a type of electron microscope capable of producing high-resolution images of a sample surface was used to determine the microstructure of obtained glass at the energy of the electron beam of 25 kV. Quantitative chemical analyses of the glass obtained by vitrification of by-product were also performed using an X-Ray energy dispersive spectrometer (EDS) coupled to the SEM. The SEM images of obtained glass at 500 and 2000 magnifications are given in *Figure 4 (a) and (b).*



(a) (b)

Figure 4. SEM images of obtained glass: (a) ×500 (bar = 50 μm); (b) × 2000 (bar =10 μm)

The chemical bond of obtained glass was investigated by using the technique of Attenuated Total Reflectance (ATR) of FT-IR Spectroscopy (Perkin Elmer Spectrum One). The spectrum was collected over the 4000 to 650 cm^{-1} wavenumber range, at a resolution of 8 cm^{-1}. FT-IR spectrum is shown in *Figure 7.* All the absorption bands are marked and explained in detail.

3. RESULT AND DISCUSSION

XRD pattern of the by-product is given in *Figure 3.* The XRD pattern indicated that by-product was defined as Na_2SiO_3. Also, XRD result showed that nonexistence of $NaBH_4$ in by-product.

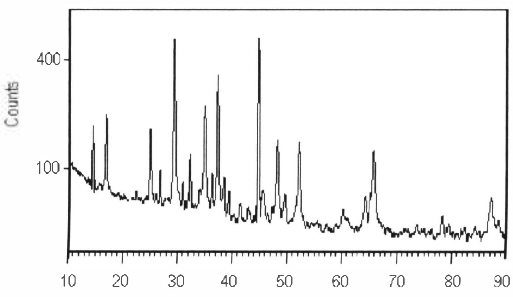


Figure 5. XRD pattern of the by-product

Morphological observations on a microscopic scale at different magnifications by SEM (see *Figure 3 (a) and (b)*) showed formation of amorphous phase. The EDS spectra in *Figure 6 (b)* and *(c)* were collected from the enclosed area 1 and 2 in *Figure 6 (a)*, respectively. According to the EDS spectrums, the chemical composition of obtained glass is calculated as 48.12% O, 51.88% Si in *Figure 6 (b)*, while the chemical composition of obtained glass is calculated as 33.85% O, 9.75% Na and 56.40% Si in *Figure 6 (c)*. The bubbles in the SEM image (enclosed area 1) are associated with SiO_2 content on 100 μm scale.

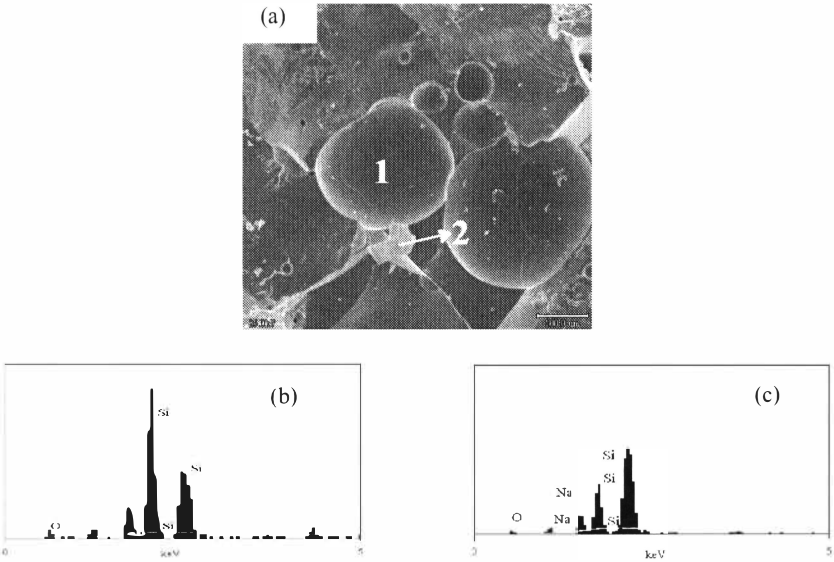


Figure 6. (a) The SEM image of obtained glass with EDS analysis, ×150 magnitude, (b,c) corresponding EDS spectra acquired from the areas of 1 and 2 in (a).

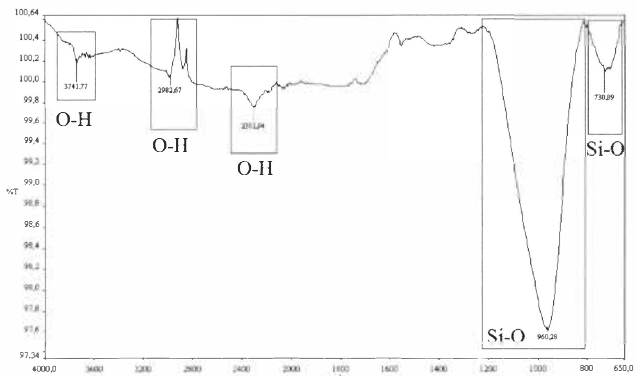


Figure 7. FT-IR spectrum of obtained glass

4. CONCLUSION

This paper presents investigation of reusing of Na_2SiO_3, obtained by $NaBH_4$ production, as a raw material in glass industry. Na_2SiO_3 was vitrified without any additives in high temperature furnace. Detailed morphological and chemical analyses of glass obtained were carried out by FT-IR and SEM-EDS analysis. In a conclusion, obtained glass can be used for decorative purpose because of greenish colour.

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