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

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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 (NaBH₄) due to its high theoretical hydrogen yield by weight (10.6%) in applications where H₂ gas is used, e.g., proton exchange membrane (PEM) fuel cells. NaBH₄ 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 Na₂SiO₃, obtained from NaBH₄ production based on the conversion reaction of borosilicate glass, as a raw material in glass industry. The by-product, was defined as Na₂SiO₃ (PDF number: 00-016­0818) 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 Na₂SiO₃ can be reused as a raw material in glass industry.

KEYWORDS

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

1 INTRODUCTION

Sodium borohydride (NaBH₄), 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, NaBH₄ is a selective specialty reducing agent used in the manufacture of pharmaceuticals and other organic compounds [3].

It is important to note that NaBH₄ can be produced by economical methods to be applied in practical use. According to the several publications, NaBH₄ was synthesized by reacting NaBO₂ with MgH₂ or Mg₂Si by annealing the mixture of these two compounds under high hydrogen pressure. Also, it was noted that NaBH₄ can be produced by reaction of MgH₂ with Na₂B₄O₇ through ball milling at room temperature [4, 5].

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In previous study of authors was expressed that process for producing NaBH₄, 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 (Na₂SiO₃) [6].

In the present work, reusing of Na₂SiO₃, obtained from NaBH₄ production based on the conversion reaction of borosilicate glass, as a raw material in glass industry was investigated. The by-product, characterized as Na₂SiO₃ (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 Na₂SiO₃ can be reused as a raw material in glass industry.

2. EXPERIMENTAL

2.1 Material

The by-product (Na₂SiO₃) which was obtained from NaBH₄ 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 NaBH₄ production process is given in Figure 1.

![Figure 1. The flow chart of NaBH₄ production](image)

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 NaBH₄ (main product) and Na₂SiO₃ (by product). It was extracted with suitable solution to separate NaBH₄ from Na₂SiO₃. 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.
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.

2.2 Characterization

Crystalline structure of by-product obtained by the NaBH₄ 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).

![SEM images of obtained glass: (a) ×500 (bar = 50 μm); (b) × 2000 (bar =10 μm)](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 Na₂SiO₃. Also, XRD result showed that nonexistence of NaBH₄ in by-product.

![XRD pattern of the by-product](a)

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 SiO₂ 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$_2$SiO$_3$, obtained by NaBH$_4$ production, as a raw material in glass industry. Na$_2$SiO$_3$ 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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