Short Communication

Dissolution of heat-treated magnesium-rich amorphous silicate fibers in a simple amino acid solution – An appendix

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This study provides the data of the concentration of released elements for the dissolution, in a glycine solution, of Mg-rich amorphous alkaline earth silicate (AES) fibers heat-treated at the temperature of 700 °C. It is shown that: a) the heat treatment at 700 °C facilitates the glass network dissolution of the fibers, b) the heat treatment also facilitates significantly the alkaline earth elements leaching in the fibers, c) the (Mg+Ca+Sr)/Si molar ratio of the released elements for the dissolution, in the glycine solution, of the fibers heat-treated at 700 °C is within the molar ratio range for the dissolution of diopside in a buffer solution. This suggests that Mg-rich AES fibers are phase separated and form diopside-like glassy phase as the chemically less durable phase resulting from the heat treatment around 700 °C.

1. Introduction

Man-made vitreous fibers (MMVFs) in the form of wools are widely used in heat resistance and thermal insulation. However, the potency for increasing risks of lung cancer caused by deposition of some MMVFs in the lungs has been pointed out [1 to 4].

In recent years, much industrial effort has gone into development of newer fibers that are more biosoluble to disappear from body tissues much more rapidly [1].

An example of the newly developed, more biosoluble fibers is amorphous alkaline earth silicate (AES) fibers [1]. The AES fibers are also exposed to circumstances at various temperatures because of their excellent heat resistance. The author's previous study [5] has shown the effects of heating on the dissolution of Mg-rich AES fibers in a glycine, a simple amino acid solution (glycine is one of the dissolved components in a physiological salt solution). The study showed that the heat treatment around 700 °C facilitates the dissolution of the AES fibers in the glycine solution. The facilitation of the dissolution was believed to be due to the phase separation of the fibers resulting from the heat treatment.

This paper provides the data of the concentration of released elements for the dissolution, in the glycine solution, of Mg-rich AES fibers heat-treated at the temperature of 700 °C as an appendix for the previous study [5] to discuss the possibility of the phase separation of Mg-rich AES fibers.

Received 31 December 2004.

2. Materials and methods

Chemical composition of the Mg-rich AES fiber samples used in this study is shown in table 1.

Chemical composition of the AES fiber samples was analyzed by a wavelength dispersion X-ray fluorescence spectrometer.

The AES fiber samples were heat-treated in an electric furnace at the temperature of 700 °C over 24 h.

Each fiber sample was first chopped until the fiber passed through a 200 mesh (pore diameter: 0.075 mm) screen. Thereafter, 1.0000 ± 0.0003 g of the chopped fiber sample was weighed into a conical beaker, and 150 ml of 2 wt% glycine solution with 5 ml of 0.05 mol/l phthalate, $C_6H_4(COOK)(COOH)$, solution (which shows pH 4) was added to the beaker. The beaker with the fiber sample and the solution was inserted into a shaking incubator bath maintained at 40 °C $\pm$ 1 K (nearly at body temperature). The shaker speed was set at 120 cycles/min and the experimental period was 50 h. After the period, the solution was separated from the fiber sample by filtration. The experimental method was the same as in [5].

The concentration of released elements (Si, Mg, Ca and Sr) for the dissolution of the fiber sample in the glycine solution was determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES).

3. Results and discussions

Table 1 shows the concentration of the released elements for the dissolution of each fiber sample in the glycine solution.

Table 1. Heat treatment temperature conditions, chemical composition of the AES fiber samples, released elements concentration, molar ratio of the released elements concentration for the dissolution of the AES fiber sample in the glycine solution and pH value of the post-reacted solution

sample no.	heat treatment in °C/h	fiber composition in wt%				concentration of dissolved element in µg/ml				molar ratio of dissolved element				pH value
		SiO_2	MgO	CaO	SrO	Si	Mg	Ca	Sr	Mg/(Mg+Ca+Sr)	Ca/(Mg+Ca+Sr)	Sr/(Mg+Ca+Sr)	(Mg+Ca+Sr)/Si	
1	untreated	76.6	17.0	0.3	5.8	53	37	2	14	0.88	0.03	0.09	0.9	7.2
1	700/24	76.6	17.0	0.3	5.8	87	131	4	50	0.89	0.02	0.09	2.0	8.0
2	untreated	74.8	14.0	9.6	1.3	54	28	22	3	0.67	0.31	0.02	0.9	7.2
2	700/24	74.8	14.0	9.6	1.3	94	127	89	13	0.69	0.29	0.02	2.3	8.2

The released Si concentration for the dissolution, in the glycine solution, of each fiber sample heat-treated at 700 °C is approximately 1.6 to 1.7 times as much as the concentration for the dissolution of the untreated fiber sample. This shows that the heat treatment at 700 °C facilitates the glass network dissolution of the fiber samples.

The released total alkaline earth (Mg+Ca+Sr) molar concentration for the dissolution, in the glycine solution, of each fiber sample heat-treated at 700 °C is approximately 3.5 to 4.4 times as much as the concentration for the dissolution of the untreated fiber sample. This shows that the heat treatment at 700 °C also facilitates significantly the alkaline earth elements leaching in the fiber samples.

The molar ratio of the released elements for the dissolution of each fiber sample in the glycine solution is also shown in table 1.

The Mg/(Mg+Ca+Sr), Ca/(Mg+Ca+Sr) and Sr/(Mg+Ca+Sr) molar ratio of the released elements for the dissolution of each fiber sample in the glycine solution remains unchanged throughout the heat treatment at 700 °C. This indicates that the heat treatment does not cause the selective leaching of specific alkaline earth elements in the fiber samples.

The (Mg+Ca+Sr)/Si molar ratio of the released elements for the dissolution, in the glycine solution, of each fiber sample heat-treated at 700 °C is approximately twice as much as the molar ratio for the dissolution of the untreated fiber sample. The (Mg+Ca+Sr)/Si molar ratio of the released elements for the dissolution of each untreated fiber sample is approximately 1. On the other hand, the (Mg+Ca+Sr)/Si molar ratio of the released elements for the dissolution of each fiber sample heat-treated at 700 °C is approximately 2. In addition, the pH of the glycine solution rises from 4 (initial pH value) up to approximately 8 throughout the dissolution of each fiber sample (table 1). It has been shown that the (Mg+Ca)/Si molar ratio of the released elements for the dissolution of diopside ($CaMgSi_2O_6$) in a buffer solution at pH 6 is in the range from 1.6 to 3.0 [6]. The (Mg+Ca+Sr)/Si molar ratio of the released elements for the dissolution, in the glycine solution, of each fiber sample heat-treated at 700 °C is within the molar ratio range of the released elements for the dissolution of diopside in the buffer solution. Therefore, the dissolution processes of Mg-rich AES fiber samples heat-treated at 700 °C, the state of which is amorphous [5], would be similar to those of diopside. It is known that a homogeneous high-silica glassy material can be phase separated into a chemically less durable phase and a silica-rich phase [7 and 8]. This suggests that Mg-rich AES fibers are phase separated and form a diopside-like glassy phase as the chemically less durable phase resulting from the heat treatment around 700 °C.

4. References

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