ETHIOPIAN INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

eISSN: 2349-5715 pISSN: 2349-5707

Volume: 10, Issue 12, Dec-2023 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980

SEPARATION OF CRYSTAL SILICON THROUGH METALLOTHERMAL REDUCTION

Jiyanova Sayyora Ibragimovna
Turaev Khayit Khudaynazarovich
Eshmurodov Khurshid Esanberdiyevich
[1]Doctoral student of Termiz State University, [2] Professor of Termiz State University, [3] Tashkent Research Institute of Chemical Technology
Email: jiyanovasayyora2021@gmail.com

Abstract: In this scientific research, research was carried out on the extraction of crystalline silicon by enriching and returning the sand of the "Jerdanak" quartz mine in Sherabad district of Surkhandarya region. Quartz sand without enrichment was analyzed by X-ray phase method, and the amount of silicon (IV) oxide (SiO_2) and additional substances was determined. This work presents the results of experiments on technical silicon extraction processes by enriching sand and then reducing it with aluminum and magnesium. The obtained samples were reanalyzed.

Key words: electricity, energy, quartz, quartzite, temperature, mineral, silicon, reducing, aluminum, magnesium, carbon, electric furnace.

Electricity in our daily life to energy was Demand year as increased is going Electric of energy main sources - oil, gas, coal, uranium and their reserves decreased to go is being observed. The last one in years scientists greenhouse gases of the amount increase surroundings environment, ecology negative effect that it is a lot about thought they say. That's why for, re recoverable energy using sources (QTEM), ecological clean electricity energy work to get out attention increased. Most efficient again recoverable energy from sources one the sun panels - solar radiation directly electricity to energy rotate will receive devices [1,2]. More than 90% of solar cells on the market today are silicon-based [3].

TS (technical silicon) used in industry is obtained by processing quartz sand. The most common modern method of obtaining TS is the reduction of silicon dioxide with coke in electric furnaces. The mixture of sand and coke enters the crater of the furnace, where it is heated to 1800-2000°C by an electric arc created between carbon electrodes. At such temperatures, the carbons of the coke and electrodes interact with silicon oxide, turning into carbon monoxide gas and returning the sand to TS [4]:

$$SiO_2+2C \rightarrow Si + 2CO(1).$$

Traditional solar cells are made from inorganic semiconductors - poly and monocrystalline silicon, gallium arsenide, etc. Such solar cells have high efficiency and long service life, but the production is very expensive [5]. In our research work, the technology of extracting technical silicon from local quartz sands and electronic grade silicon was studied. Most of TS is used in the metallurgical industry as a component of alloys, for example, in the smelting of bronze, iron and steel, as well as as an alloying element or modifier of metal properties [6].

Taking TS in the laboratory returners as magnesium and from aluminum use can:

$$SiO_2+2Mg = Si + 2MgO \ (3) \ [7].$$

SiO_2 scientists from Annaba University of Algeria stated that magnesiothermic reduction is a widely used method in the laboratory due to its simplicity, low temperature, and low production cost.

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 10, Issue 12, Dec-2023 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980

However, the inevitable formation of magnesium silicide (Mg_2Si) during the reaction reduces the use of this method. In their work, they worked on obtaining high-purity silicon by pretreatment of quartz sands by acid washing [8,9]. Scientists from Rajshahi University in Bangladesh have studied the technology of obtaining silicon (Si) from Padma river sand by aluminothermic reduction Si. The SiO_2 content before and after beneficiation of the sand was found to be around 88% and 95% when examined by XRF (X-ray fluorescence). In the aluminothermic process, aluminum (Al) was used to reduce SiO_2 (sand) and produce Si.

$$3SiO_2 + 4Al = 3Si + 2Al_2O_3 (4)$$

(4) the reaction was carried out at a temperature of 1200-1300°C. Then, the sample formed as a result of the reaction was further purified by acid washing. Optical microscopy and SEM (scanning electron microscopy) were used to determine the average sand particle size and surface morphology before and after enrichment, respectively [10.11].

The purpose of the study

Technical silicon extraction by beneficiation, purification and metallothermic reduction of quartz sand.

Research tools and methodology

Quartz sand - occurs in nature in various purity. Sand contains other components such as aluminum, sodium, calcium and potassium (feldspar minerals). The chemical formula is SiO_2. Quartz has piezoelectric properties. Hardness 7. Density 2.65 g/cm ^{3}. Liquefaction temperature 1710°C, when cooled quartz the so -called window to the body becomes Single crystals less occurs and very high is evaluated [12].

Aluminum (Al) - silver of the 13th group of the periodic system white metal is considered Al is the most abundant metallic element in the earth's crust, but it is never found in its elemental state in nature. It is mainly in the form of very stable oxides: hydroxides and silicates. Aluminum has many useful properties. It is flexible and light. Pure aluminum is relatively soft and weak, but forms many strong alloys. It has high thermal and electrical conductivity. The aluminum oxide film attached to the surface makes it corrosion resistant. Most acids are resistant, but alkaline solutions dissolve the oxide film and cause rapid corrosion [13].

Magnesium (Magnesium), Mg - Mendeleev's periodic table to the II group of the system belongs to chemical element; alkaline earth to metals enters Order number 12, atomic mass 24,305. Magnesium in 1829 French chemist Magnesium Bussy magnesium to chloride potassium steam influence Magnesium metal in case separate received Magnesium mass in terms of land 2.35% of the post organize does 100 of magnesium more than minerals there is. Magnesium light silver colorful metal as manifestation will be Subtle material is water with to the reaction entering, hydrogen, flammable the gas, but this reaction sodium or of lithium water with reaction such as strong it's not. Delicate when dispersed, it is very fast ignites Strong white fire with burns [14]. Ours research Al and Mg in our work returning as used.

X- ray diffraction (XRD) is an analytical method that provides information on crystal structures, phases, crystal orientations (texture), and other structural parameters, such as average size, crystallinity, deformation, and crystal defects. X-ray diffraction peaks are formed by constructive interference of monochromatic X-rays scattered at certain angles from each lattice plane in the sample. The highest intensity is determined by the distribution of atoms in the lattice [15]. In our work, a powder diffractometer manufactured in Japan "SHIMADZU" XRD-6100 was used.

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 10, Issue 12, Dec-2023 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980

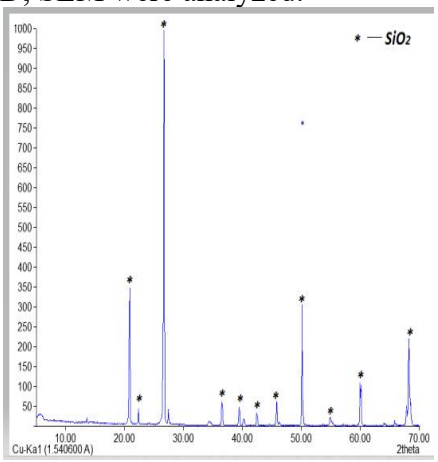
A scanning electron microscope (SEM) is a device used in many industrial laboratories to analyze research results. Due to its large focal depth and X-ray microanalysis capabilities, SEM is often used in materials science, including polymers, to elucidate the microscopic structure or distinguish between multiple phases [16]. In this research work Microstructure analysis was performed with Jeol JSM-IT200LA (Japan) SEM - EDS energy dispersive analysis application.

Enrichment - when any natural raw material is mined, it contains a certainamount of additional impurities in addition to useful minerals. Enrichment is the increase of beneficial components in the mineral content. Different methods of enrichment of raw materials are used depending on their aggregate state. Grinding jaw grinder, conical feeling machines, shaft chopper, hammered grinder, spherical in crushers (mills). done is increased. Mechanical enrichment methods include sorting, gravity separation, electromagnetic, electrostatic separation, flotation methods [17,18,19].

Experimental part

XRD and SEM analyzes were carried out before enrichment of quartz sand brought from the "Jerdanak" quartz mine of Sherabad district. The analyzed sand sample is 0.63 sieve (D120/H38 steel wire).

Because of C to beat the sand gravel and clay can distinguish [20]. Announced in a nanomill where the sand rotates 400 times per minute (Retsch PM 400 ballmill) 200-300 milled to nm. Crushed quartz 18 g of sand, technical taking 10.8 g of aluminum mixed (based on reaction 4). Primary substances $\frac{SiO_2}{Al} = \frac{3}{4}$mol in proportion received _ Same also according to the 3rd reaction , crushed quartz 12 g of sand , 9.6 g of magnesium ($\frac{SiO_2}{Mg} = \frac{1}{2}$ mol ratio) was mixed . Ready mixtures at a temperature of 1300°C for 6 hours during in the reactor returned. Received products distilled in water 4 times after washing _ acids using processing given _ Filter paper (diameter 15 cm FB - lll using GOST 12026-76). from filtered then at a temperature of 100°C muffle in the oven dried. Received of samples physical and chemical properties, element composition determination in order to XRD, SEM were analyzed.



Strongest 3 peaks

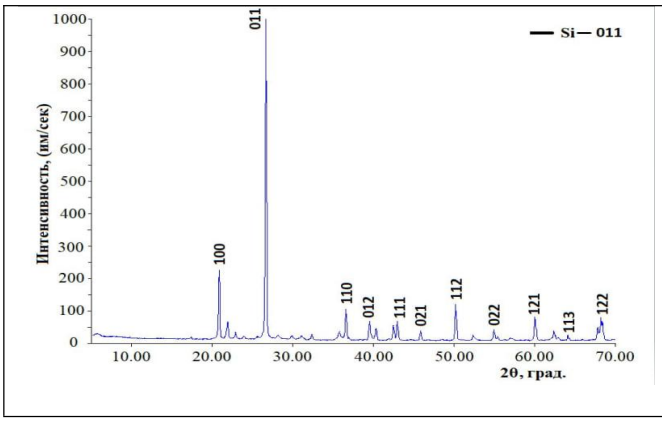
no. peak no.	2Theta (deg)	d (A)	I/I1	FWHM (deg)	Intensity (Counts)	Integrated Int (Counts)
1 3	26.7832	3.32592	100	0.26260	22163	124558
2 13	68.2891	1.37239	43	0.16570	9538	33468
3 1	20.9592	4.23508	34	0.23270	7618	38398

Peak Data List

peak no.	2Theta (deg)	d (A)	I/I1	FWHM (deg)	Intensity (Counts)	Integrated Int (Counts)
1	20.9592	4.23508	34	0.23270	7618	38398
2	22.4679	3.95400	6	0.14460	1397	4479
3	26.7832	3.32592	100	0.26260	22163	124558
4	27.5579	3.23415	7	0.15840	1485	5980
5	36.6044	2.45296	11	0.18460	2403	9657
6	39.5304	2.27787	9	0.17120	1912	7181
7	42.5276	2.12401	6	0.17410	1315	4989
8	45.8775	1.97641	12	0.16090	2698	10294
9	50.1895	1.81625	30	0.19400	6667	26911
10	54.9450	1.66976	4	0.21070	931	6028
11	60.0637	1.53912	22	0.23530	4842	23178
12	67.8876	1.37953	10	0.18420	2280	9914
13	68.2891	1.37239	43	0.16570	9538	33468
14	68.6594	1.36589	10	0.14020	2252	7746

Figure 1. XRD analysis graph of natural quartz sand

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 10, Issue 12, Dec-2023 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980



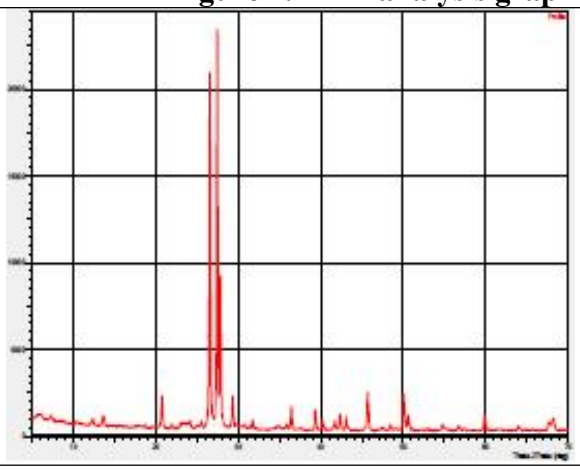
Strongest 3 peaks

no. peak	2Theta	d	I/I1	FWHM	Intensity	Integrated Int
no.	(deg)	(A)		(deg)	(Counts)	(Counts)
1 2	26.9499	3.30572	100	0.20650	29877	134440
2 1	21.1735	4.19270	45	0.19860	13475	57652
3 8	42.6966	2.11600	25	0.13540	7580	23051

Peak Data List

peak	2Theta	d	I/I1	FWHM	Intensity	Integrated Int
no.	(deg)	(A)		(deg)	(Counts)	(Counts)
1	21.1735	4.19270	45	0.19860	13475	57652
2	26.9499	3.30572	100	0.20650	29877	134440
3	27.7771	3.20913	8	0.19390	2492	13134
4	28.7435	3.10339	6	0.22230	1760	10838
5	36.7815	2.44155	7	0.17980	2194	8270
6	39.7221	2.26732	5	0.13480	1445	4410
7	40.5926	2.22068	4	0.15770	1201	4373
8	42.6966	2.11600	25	0.13540	7580	23051
9	46.0580	1.96908	6	0.15250	1784	6088
10	47.5812	1.90954	3	0.22550	907	5728
11	50.3945	1.80934	11	0.17690	3386	13770
12	55.1331	1.66451	3	0.15780	999	3420
13	60.2134	1.53565	19	0.15950	5574	19850
14	67.9848	1.37779	6	0.18200	1723	6771
15	68.4775	1.36908	7	0.33290	2195	14382

Figure 2. XRD analysis graph of quartz sand treated with magnesium



Strongest 3 peaks

no. peak	2Theta	d	I/I1	FWHM	Intensity	Integrated Int
no.	(deg)	(A)		(deg)	(Counts)	(Counts)
1 3	27.4796	3.24319	100	0.17220	21331	85658
2 2	26.5808	3.35078	67	0.22660	14315	69992
3 4	27.8614	3.19961	44	0.17800	9382	40683

Peak Data List

peak	2Theta	d	I/I1	FWHM	Intensity	Integrated Int
no.	(deg)	(A)		(deg)	(Counts)	(Counts)
1	20.8070	4.26572	9	0.17730	1953	8420
2	26.5808	3.35078	67	0.22660	14315	69992
3	27.4796	3.24319	100	0.17220	21331	85658
4	27.8614	3.19961	44	0.17800	9382	40683
5	29.3699	3.03861	9	0.18080	1826	8181
6	36.4628	2.46216	7	0.16980	1533	6780
7	39.3700	2.28678	7	0.16780	1479	5449
8	40.2341	2.23964	3	0.14960	728	2485
9	42.3682	2.13163	5	0.16620	1101	4210
10	43.0831	2.09790	4	0.14690	921	3248
11	45.7185	1.98291	13	0.18100	2746	11490
12	50.0689	1.82034	12	0.17550	2651	10830
13	50.6256	1.80162	5	0.16560	1110	4422
14	59.8876	1.54322	5	0.20450	1097	5419
15	67.6714	1.38341	3	0.19490	735	3122
16	68.1557	1.37475	4	0.35730	754	6086

Figure 3. XRD analysis graph of quartz sand treated with aluminum

Analysis of results

As can be seen from the graphs above, the intensity was relatively high when the X-rays were incident at an angle of 25°-30°. It was found that the intensity at these incidence angles was 22163 in natural quartz sand, 29877 when refracted with magnesium, and 21331 when refracted with aluminum. The separation yield of technical Si was found to be 58% when reduced with magnesium and 43% when reduced with aluminum.

Si reacts with Mg at 1300°C due to the formation of magnesium silicide, and in the reaction with Al, the yield was lower due to the lower temperature.

References:

1. Baranov N.N. Direct conversion of energy for autonomous energy. //Energy: economy, technology , ecology.

2. Strebkov D.S. The role of solar energy in future energy // M.: Energeticheskaya politika, 2005.-№°2.-C.27-36.

3. Kozlov A.V., Yurchenko A.V. The long-term prediction of silicon solar batteries functioning for any geographical region. // Proceedings of the 22nd European PV Solar Energy Conference and Exhibition, Milan 3-7 September 2007 pp. 3019 - 3022

4. Ataev.E.K . , Matyakubov A.A. , Batmanov.B.Kh . Enrichment of KARAKUM quartz sand. Mary, Turkmenistan. 2022 _ _

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 10, Issue 12, Dec-2023 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980

5. X. Su, Q. Wu, J. Li et al., "Silicon-based nanomaterials for lithium-ion batteries: a review," *Advanced Energy Materials*, vol. 4, no. 1, article 1300882, 2014.

6. Abdurakhmanov B.M., Kurbanov M.Sh., Vecher A.K. Physical basis for increasing the profitability of the production of technical silicon and silicon alloys // Uzbek Physical Journal 2020. V. 22, No. 3, pp. 188-198. (10.00.00; No. 5).

7. Budagyan B.G., Sherchenkov A.A., Berdnikov A.E., Chernomordik V.D. High-speed method for deposition of amorphous silicon. Microelectronics, 2000, v. 29, no. 6, p. 442-448.

8. Saida Haouli, Said Boudebane Ian J. Slipper, Samia Lemboub, Piotr Gębara, Samiha Mezrag // Combustion synthesis silicon by of magnesiothermic reduction// https://doi.org/10.1080/10426507.2017.1416615
9. Azam Rasouli, Maria Tsoutsouva, Jafar Safarian, Gabriella Tranell // Kinetics of Magnesiothermic Reduction of Natural Quartz // *Materials* 2022, *15*(19), 6535; https://doi.org/10.3390/ma15196535
10. Abdul Kuddus., Ataur Rahman., Abu Bakar Md. Ismail.// Possibility of Alumino-thermic Process to be Used for the Extraction of Silicon from the Sand of the Padma River//January 2017 .Conference: International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering IC4ME2-2017,At: University of Rajshahi
11. Dietl, J., Holm, C., Sirtl, E. (1982). Aluminothermic Reduction of Quartz Sand. In: Bloss, W.H., Grassi, G. (eds) Fourth E.C. Photovoltaic Solar Energy Conference. Springer, Dordrecht. https://doi.org/10.1007/978-94-009-7898-0_154
12.Götze, J.; Möckel, R. Quartz: Deposits, Mineralogy and Analytics; Springer: Berlin/Heidelberg, Germany, 2012; pp. 1-360.
13. William B. Frank., Warren E. Haupin,, Helmut Vogt., Marshall Bruno., Jomar Thonstad., Robert K. Dawless., Halvor Kvande., Oyebode A. Taiwo// Aluminum// First published: 15 July 2009 https://doi.org/10.1002/14356007.a01_459.pub2
14. Aghion, E., Golub, G. (2006). Production Technologies of Magnesium. In: Magnesium Technology. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-30812-1_2
15. Andrei A. Bunaciu., Elena gabriela Udriştioiu., Hassan Y. Aboul-Enein.//X-Ray Diffraction: Instrumentation and Applications//Pages 289-299 | Published online: 21 May 2015 https://doi.org/10.1080/10408347.2014.949616
16. Omoniyi Kolawole Pereao. Scanning Electron Microscopy (SEM). In: Electron Microscopy of Polymers. Springer Laboratory. Springer, Berlin, Heidelberg. 2008 https://doi.org/10.1007/978-3-540-36352-1_5
17. Hasan Hacifazlioglu.// Enrichment of Silica Sand Ore by Cyclojet Flotation Cell//Pages 1623-1632 | Received 23 May 2013, Accepted 07 Feb 2014, Published online: 08 Jul 2014 https://doi.org/10.1080/01496395.2014.893357
18. Efremenkov, V.V. Integrated Approach to the Design and Construction of Enterprises and Sites for the Enrichment of Quartz Sand. *Glass Ceram* **71**, 369-372 (2015). https://doi.org/10.1007/s10717-015-9690-x
19. Konev N. N.// Magnetic enrichment of quartz sands. Analysis of separator operation// November 2010. Glass and Ceramics 67(5):132-137DOI:10.1007/s10717-010-9246-z
20. Tafraoui A., Lebaili S., Slimani A. *Res. J. Appl. Sci.* **1**, 1 (2006).