УДК: 553.576.06(043)

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BENEFICIATION STUDIES OF THE QUARTZ DEPOSITS OF WADI MUBARAK AREA IN THE EASTERN DESERT OF EGYPT, FOR IDENTIFYING THE POSSIBILITY OF PRODUCTION OF HIGH PURITY QUARTZ CONCENTRATE

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The present study deals with the geochemical and technical qualifications of the quartz deposits of Wadi Mubarak area in the Eastern Desert of Egypt, as well as the beneficiation processes necessary for upgrading these deposits to reach the qualification of high Purity quartz (HPQ) for use as a raw materials in some high-tech industries.

Introduction

The demand for the raw material quartz is increasing worldwide, in particular, the demand for high-purity quartz (HPQ; e.g. /1, 2/). Therefore, quartz has been recently considered as a strategic mineral because it represents the raw material for special applications in high-tech industry. The trace-element contents of quartz are its most important quality criteria. Quartz is designated high purity when it contains less than 50 μg g−1 of impurities /3/, which mainly comprise structurally bound trace elements (B, Li, Al, Ge, Ti, Fe, Mn, Ca, K, Na and P) in the quartz lattice, also micro-inclusions of minerals and trapped fluids. HPQ is rare in nature and larger deposits even more so. The few HPQ deposits found around the world include certain types of quartz-rich granitic pegmatite /4, 5/ and hydrothermal quartz veins. Al and Ti besides Li, P and B are used as indicators of the quality of the quartz. These elements are important quality-determining trace elements depending on the industrial application being considered for the raw material. High Ti concentrations, for example, change the absorption behavior of optical silica glass. Metallic silicon and polysilicon are bred in quartz crucibles, and high P and B concentration in the quartz glass of the crucibles contaminates the growing silicon crystals, which are used for solar cells or computer chips. Moreover, Al, Ti and Li are difficult to remove during refinement of quartz. Therefore, the industry is highly interested in quartz resources with low initial trace-element concentrations to lower production costs and to improve the quality of the quartz products. But when these resources are not available affordable industrial dressing becomes a necessity /6/.

Methods and Techniques

The methods and techniques that have been applied on the quartz deposits of Wadi Mubarak are: 1) Geochemical analyses by using the XRF technique and 2) Beneficiation processes (Floatation followed by wet magnetic separation). All the geochemical analyses and upgrading processes were carried out in the labs of the Egyptian geological survey.

Beneficiation processes of Wadi Mubarak quartz deposits

The processing technologies have to be adapted for specific requirements of quartz raw materials. Only in the rarest instances, it is possible to use raw materials right away without some prior processing. Processing technologies therefore, play a central role in the value enhancement chain and maximum utilization of quartz. These technologies are the decisive factor in the commercial success of a deposit. Process development always starts out from chemical and physical characteristics of natural quartz. In the past, special attention was devoted to the development of the processes regarding sample preparation and procedures for the detection of trace impurities in quartz up to the ppb-area /7/. Laboratory tests must be done to figure out which process combination will lead to an optimal result at the end.

The beneficiation procedures applied on some of Wadi Mubarak quartz samples of variable silica content and impurities are froth Floatation followed by wet magnetic separation.

The selected quartz samples were subjected to grinding processes which resulted in quartz powder of about 60 to 100 micron grain size /8/. This quartz powder was treated using froth Floatation. The froth Floatation process is selected as the result of chemical analyses of the selective raw quartz samples which show an increase of Al_2O_3, and loss on ignition, which reflect the presence of alkalis and mica impurities. Therefore, it is clear that the main target of the Floatation process is to remove the excess of alumina bearing minerals.

The wet high intensity magnetic separation method is also used to reduce the Fe-oxides content. The description of froth Floatation and magnetic separation methods are given hereunder:

Froth Floatation process

Two quartz samples were subjected to the Floatation process. The obtained samples by Floatation were subjected to chemical analyses and the obtained analyses are given in table 1.

Table 1

Chemical analyses of the quartz samples before and after Floatation

Sample №		*Before Floatation*		*After Floatation*	
		M_1	*M_2*	*M_{1*}*	*M_{2*}*
Concentrate	Wt%	–	–	99.83	99.85
	Wt gm	–	–	465.23	485.3
Tails	Wt%	–	–	0.17	0.15
	Wt gm	–	–	0.77	0.7
Major oxides (wt%)					
SiO_2		99.60	99.50	99.72	99.62
TiO_2		< 0.01	< 0.01	< 0.01	< 0.01
$A1_2O_3$		0.19	0.16	0.05	0.04
Fe_2O_3		0.02	0.014	0.016	0.010
MnO		< 0.01	< 0.01	< 0.01	< 0.01
MgO		< 0.01	< 0.01	< 0.01	< 0.01
CaO		< 0.01	< 0.01	< 0.01	< 0.01
Na_2O		< 0.01	< 0.01	< 0.01	< 0.01
K_2O		< 0.01	< 0.01	<0.01	<0.01
P_2O_5		0.01	0.01	0.01	0.01
L.O.I		0.089	0. 192	0.08	0.1
Some Trace elements (ppm)					
Cr		3	4	2.8	3
Co		5	5	5	5
Ni		4	12	3.5	7
Cu		< 1	< 1	< 1	< 1
Zn		4	7	4	7
Ga		< 1	< 1	< 1	< 1
As		< 1	< 1	< 1	< 1
Zr		5	5	< 1	< 1
Pb		7	7	4.2	4.2
U		4	< 1	3	< 1

- **Devices used:** American Floatation device model Denever of speed 1000 turns/ Minute, pH Meter Device.
- **Chemicals used:** Armac C "collection" 1.5 kg / ton, Pine oil "cause foam" 200 gm / ton, Kerosene 1.5 kg / ton, H_2SO_4 Acid 1.5 kg/ton, HCL Acid 1.5 kg /ton.
- **Floatation steps:**

1. Weight and record the sample.
2. Put the sample in a mixing cup of ratio 1:4 solid to liquid.
3. Adjust pH at 2–4 using H_2SO_4.

4. Add Armac C "Collector"+ Kerosene + Pine oil. And operate the device and Floatation process start.

As shown in Table 1, it is clear that SiO_2 content is increased (from 99.50–99.60 before Floatation to 99.62–99.72% after Floatation). Also there is a marked decrease of A12O3 (from 0.16–0.19% before Floatation to 0.04–0.05% after Floatation) and Fe_2O_3 (from 0.014–0.02% before Floatation to 0.01–-0.016% after Floatation) to a noticeable percents.

Some of the trace elements such as Cr, Ni, Zr and Pb also displayed a noticeable decrease after froth Floatation while the rest of them did not affected.

Magnetic separation process

Apparatus

Wet magnetic separation device of separator type LHWL at separation efficiency from 200 to 2000 Jaws.

Procedure

The separation is done under magnetic field at 2000 Jaws. The samples pass through dipoles with the presence of thin stainless steel wire. The magnetic part of the two poles attracts to themselves, the electric current must be off, and the vessel must be substituted and washed to take off the unmagnetic samples. This operation must be done twice for each sample, the first for rough separation and the second for cleaning and assuring quality separating and minimizing ferrous impurities in the nonmagnetic products. The device is capable to separate all iron oxides that are represented by magnetite and ilmenite, in addition to the heavy silicates and others. The single sample in the single time is equal 100 gms. The apparatus separates only the fine grain sizes (-50 microns) using the wet method in a ratio of 1 (solid): 2 (liquid).

The analyses results of the floated quartz samples that subjected to magnetic separation process are shown in Table 2.

Table 2

Chemical analyses of the quartz samples before and after Floatation, as well as after wet magnetic separations

Sample №	*Before Floatation*		*After Floatation*		*After wet magnetic separation*	
	M_1	M_2	M_{1*}	M_{2*}	M_{1*}''	M_{2*}''
Major oxides (wt%)						
SiO_2	99.60	99.50	99.72	99.62	99.72	99.62
TiO_2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
$A1_2O_3$	0.19	0.16	0.05	0.04	0.05	0.04
Fe_2O_3	0.02	0.014	0.016	0.010	0.016	0.010
MnO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
MgO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
CaO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Na_2O	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
K_2O	< 0.01	< 0.01	<0.01	<0.01	< 0.01	< 0.01
P_2O_5	0.01	0.01	0.01	0.01	< 0.01	< 0.01
L.O.I	0.089	0. 192	0.08	0.1	0.07	0.09
Some Trace elements (ppm)						
Cr	3	4	2.8	3	< 1	< 1
Co	5	5	5	5	5	5
Ni	4	12	3.5	7	3.2	5.5
Cu	< 1	< 1	< 1	< 1	3.2	3.2
Zn	4	7	4	7	6	8
Ga	< 1	< 1	< 1	< 1	< 1	< 1
As	< 1	< 1	< 1	< 1	< 1	< 1
Zr	5	5	< 1	< 1	< 1	< 1
Pb	7	7	4.2	4.2	4.5	4.5
U	4	< 1	3	< 1	3	< 1

From table 2, it is clear that there is no change in the contents of SiO_2, Al_2O_3 and Fe_2O_3. On the other hand, there is a marked decrease in the contents of P_2O_5 (from 0.01% after Floatation, to < 0.01% after magnetic separation).

Some of the trace elements such as Cr and Ni also displayed a noticeable decrease of contents after magnetic separation while Cu, Zn and Pb displayed a little increase of contents after wet magnetic separation. The rest of trace elements did not display any response to the wet magnetic separation.

After beneficiation processes (froth Floatation and wet magnetic separation, the quartz deposits of Wadi Mubarak area are qualified to be used for the production of silicon carbide (SiO_2 (99.50 to 99.75%), Al_2O_3 (0.04 to 0.05%), Fe_2O_3 (0.05 to 0.1%) and CaO+ MgO ≈1.1% /9/).

Discussion

Geochemical studies revealed that Wadi Mubarak quartz deposits can be classified as pure to very pure quartz (SiO_2 99% to ≥ 99.5 %) owning to their silica content which ranges from 99.50 to 99.60% with an average content 99.55% /10/. Also they are characterized by low contents of Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O and P_2O_5. Therefore, these deposits, without treatments, match well the requirements of the Aluminum (Si minimum 98 wt%, Fe maximum 0.02–0.05 wt% and Ca from 0.015–0.3 wt % /11/) and Ferrosilicon alloy (SiO_2 > 98%, Al_2O_3 < 0.4%, Fe_2O_3, CaO and MgO ≤ 0.2% /9/) industries.

The quartz deposits of Wadi Mubarak were beneficiated with froth Floatation followed by wet magnetic separations. The beneficiation by froth Floatation resulted in a marked increase in the SiO_2 content and minimized the $A1_2O_3$ and Fe_2O_3 content to a noticeable percent, hence it is recommended to use this method in processing of quartz deposits with aluminum and iron bearing deposits. While the beneficiation of the quartz deposits of Wadi Mubarak with wet magnetic separations after the froth Floatation, displayed no changes in the contents of SiO_2, Al_2O_3 and Fe_2O_3, but only decreased the contents of P_2O_5. Thus the beneficiation by wet magnetic separation has a little effect on the upgrading of the quartz deposits of Wadi Mubarak.

Conclusion

The high degree of purity of the quartz deposits of Wadi Mubarak area and their remarkable geochemical characteristic (high contents of SiO_2 and low contents of Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O and P_2O_5) have nominated and qualified these deposits, even without beneficiation, to be used in hi-tech industries such as Aluminum alloy and Ferrosilicon alloy industries.

The beneficiation process by froth Floatation has qualified the quartz deposits of Wadi Mubarak area to be used for the production of silicon carbide.

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