Mini Review

A Reflection on China's high purity quartz industry and its strategic development

Abstract

This paper reviews China's high purity quartz (HPQ) industrial development and presents thoughts on its strategic development by comparing China's HPQ industrial processing techniques with its counterparts in developed countries. Researches on quartz natural characteristics, resource exploration, physical-chemical purification methods and utilization are documented. Market prospects of HPQ are also presented. To develop HPQ industry, China needs to locate new high purity SiO_2 deposits and advance purification technologies.

Keywords: high purity quartz (HPQ), purification methods, natural characteristics of quartz deposits, strategic development

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Introduction

High purity quartz (HPQ) is characterized by high component rates of SiO_2 (over 99.99%), almost void of metal contaminations such as iron, titanium, chromium, zirconium, lithium, potassium, sodium and hydroxyl (OH^-). Naturally-occurring high purity SiO_2 deposits are geologically rare, and the largest known occurrence is in Alaskite igneous rocks near Spruce Pine, North Carolina, USA. (SiO_2 99.97%).

HPQ is a main raw material for producing monocrystalline silicon, polysilicon, quartz glass, optical fiber, solar cells and integrated circuit boards, and most HPQ products are made from natural crystal or quartz resources. Since 1970s, developed countries have been the leaders in HPQ processing techniques.

Before 1970s, HPQ was made from pure crystals. Industrial utilization soon made the natural resource scarce. In 1990s, developed countries started to produce HPQ from quartz ore. Two researchers (Kemmochi and Stato) successfully made HPQ powder from quartz mineral.[1,2]

China has seen an increasing demand for HPQ products due to its economic restructuring and industrial upgrading. Recent development in photovoltaic, electronic information and high-end electric light source industries has resulted in a growing demand for HPQ products. According to industrial expert forecasts, the demand is expected to grow even faster in the future.

However, domestic technology has been inadequate, and China has been largely dependent on imports for HPQ products. Most of Chinese quartz products are below medium grade, applicable only to low-end industries. To produce high-end quartz glass and components, China has to import pure quartz products or even HPQ bars and ingots.

China's on-going economic transformation and industrial upgrading calls for an exponentially increasing need for HPQ products. Therefore, it is of strategic importance for China to, on the one hand, explore new HPQ deposits, and on the other hand advance HPQ processing technologies.

Natural affinity of quartz deposits in China

As a major rock-forming mineral or as placer deposits, quartz is abundant in nature, but resources of high purity levels are rare. Among the naturally-occurring ores, only crystal, vein quartz, metamorphic quartzite and pegmatite are high in purity, and can be ideal raw materials for HPQ products.

China has more lean quartz deposits than rich ones. Most of the quartz deposits are associated resources. Moreover, varying crystal component levels in different locations cause the inconsistence of quality, making China unable to provide standardized material for large-scale HPQ production.

While large, good quality deposits have been located in Xinyi in Jiangsu, Fengyang in Anhui, Gongan in Hubei and Wucai in Inner Mongolia, limited processing techniques disable the making of competitive products. Most of the quartz ore is made into low value-added products such as silicon powder, glass, refractories, carbide and fused silica.

For instance, Xinyi quartz ore deposit of Northern Jiangsu Province, the largest high quality quartz sand deposit in China, has been unable to meet high-end domestic industrial needs, mainly due to unstable quality (Table 1), although research-enterprise collaborations have been established there.

Table 1 Mineral components of quartz sand in Xinyi quartz ore deposit, Northern Jiangsu Province

Ore type	quartz %	feldspar %	quartzite block %	chalcedonite, rutile, ilmenite %	chlorite, pyrolusite, mica %	rock debris %
original ore	62	33	2	<1	trace	1
taken- off mud	67	27	1	<1	substantial reduction	<1

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HPQ is defined in relation to its total and elemental contamination. Although the contamination can be removed using modern processing methods, structurally bound substitutional elements such as aluminium, titanium, and lithium are impossible to remove, thus affecting the purity of the products. The control over the uniformity of crystal structure and the consistency of inherent chemicals is of crucial importance to the quality of HPQ products.

Traditional HPQ production includes a series of processes such as crushing, screening, floatation, acid-washes using hydrofluoric acid, magnetic separation and/or other physical-chemical techniques. In developed countries, deep purification techniques includes chloridizing roasting, irradiation, high temperature superconducting magnetic separation, high temperature vacuum purification, calcining-acid quenching, microwave burst and ultrasonic dispersion purification. A good example of companies is the Quartz Corporation that mines at Spruce Pine in the USA. It crushes screens and mills the material to sand at the mine site before sending the material to Norway for the high-end flotation processing steps to remove the remaining unwanted deleterious elements.

China started making HPQ materials from ordinary quartz ores in late 1980s, but the output could only be used in medium or low-grade quartz products. From the start of the 21st century, China strengthened its research in pure quartz production.

Iron and aluminium impurities are the main contaminations that need to be removed from quartz ore. To purify quartz ore, chemical purification methods have traditionally been the preferred choice. One or more kinds of inorganic acids is used to achieve higher efficiency. Aluminium removal processes mainly include desliming and flotation, during which feldspar and quartz are separated using fluoride acid. The strong acidic condition often leads to environmental problems and equipment erosions.[3]

In recent years, China has attached great importance to quartz purification innovations, especially in the purification and utilization of common quartz ores. With improved quality, some of Chinese quartz products can suffice medium and low grade industrial requirements. With raised production capacity, China now exports quartz powder measured in tens of thousands of tons every year.[4]

Chinese researchers are innovating HPQ processing techniques to balance high efficiency and environmental impact. Alternative, environmentally friendly reagents are being experimented with the use of oxalate and phosphoric acid under ultrasonic and microwave conditions.[5]

Market prospects

Naturally-occurring ultra-pure SiO_2 (greater than 99.997%) is geologically rare and commands a significant premium over the price of lower grade material. As shown in Table 2, prices of low to medium grade HPQ material are typically about US$300-US$500/t, while the best processed silica rock can sell for over US$5,000/t.

Table 2 Typical silica sand and quartz specifications by market

Type or Application	SiO_2 minimum %	Other Elements maximum %	Other Elements maximum ppm	Market Size Mtpa	Typical price US$/tons
Clear glass-grade sand	99.5	0.5	5,000	>70	$30
Semiconductor filler, LCD and optical glass	99.8	0.2	2,000	2	$150
'Low grade' HPQ	99.95	0.05	500	0.75	$300
'Medium grade' HPQ	99.99	0.01	100	0.25	$500
'High grade' HPQ*	99.997	0.003	30	<0.1	>$5,000

Technological disadvantage limits China's HPQ production development, and China has been reliant on imports and susceptible to global market fluctuations. Stringent international supply often leads to the surge of import prices, which in turn raises the cost of production.

For a long time, China had to rely totally on imports. The year 2007, for instance, witnessed a total import of 30,000 tons of HPQ sand. Some imports from Japan even trace their primitive origin back to China, where they are exported as raw materials to Japan. Unimin Corporation, a US-based global leader of HPQ production, cut down its production in recent years with the wane of deposits. As a result, many Chinese enterprises suffered severe losses, especially solar photovoltaic businesses.

In recent years, there has been considerable progress in HPQ production in China. The cooperation between enterprises and research institutions, e.g. the Jiangsu Pacific Quartz Co. Ltd. set up in 2010, has improved the quality of products and created bright prospects for HPQ production in China. Despite the technological advances, there still exists room for improvement for Chinese enterprises compared with their counterparts in developed countries.[6]

With the development of modern industries, demands for HPQ sand is increasing. The following shows the main demand in 2015.

i. Annual consumption of quartz glass: about 3,000 tons;

ii. Electric light source : 1000 tons/year;

iii. Other areas were estimated at 30,000 tons/year.

Conclusion

HPQ products are widely used in electronics, tele-communications, aerospace, military and solar photovoltaic industries. Crucial to high-tech industrial development, HPQ supply plays an increasingly significant role in national strategic planning.

HPQ sand used to be obtained from high-grade natural crystal resources. In recent decades, rising global demands consumed high grade natural deposits, making this scarce resource all the more

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inadequate. Alternative resources, i.e. new HPQ deposits, therefore, must be found. Therefore, it is important to strengthen the geological survey of high quality siliceous mineral resources. It is also important for China to improve the expertise in quartz mining and processing techniques. To strengthen China's competence in high-end quartz production, research and innovation need to be made in the following four aspects:

i. Studying the characteristics and formation of quartz sand deposits in regard to its industrial significance;

ii. Analyzing the physical and chemical properties of quartz sands;

iii. Evaluating whether quartz sand deposits meet high-end product requirements;

iv. Researching approaches to the comprehensive utilization of quartz sand ore as raw materials for HPQ products.

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Conflict of interest

There is no conflict of interest in this work.

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