Electronic Supplementary Information

Weijun Song[a,b], Shizhong Yang[a], Serge Maurice Mbadinga[a], Xiaoyong Sun[c] and Bozhong Mu[*a]

[a] State Key Laboratory of Bioreactor Engineering and Institute of Applied Chemistry, East China University of Science and Technology, Shanghai 200237, P.R. China

[b]School of Chemical Engineering, Qinghai University, Xining, 810016, P.R. China

[c]YXLON (Beijing) X-Ray Equipment Trading Co., Ltd,100081, P.R. China

[*]Corresponding Author: Bo-Zhong Mu

E-mail: bzmu@ecust.edu.cn

Phone: +86 21 64252063; Fax: +86 21 64252485

1. Materials and methods

NaCl (AR, ShangHai LingFeng Chemical reagent Co.,LTD, China)
KCl (AR, ShangHai LingFeng Chemical reagent Co.,LTD, China)
$MgCl_2$•$6H_2O$ (AR, ShangHai LingFeng Chemical reagent Co.,LTD, China)
$CaSO_4$•$2H_2O$ (AR, ShangHai LingFeng Chemical reagent Co.,LTD, China)

Pure carnallite was crystallized in our lab. It was obtained by means of solvent evaporation. An almost saturated solution containing KCl 3.160 g , MgCl2•$6H_2O$ 56.899 g and H_2O 39.968 g was evaporated at 20℃, the container was covered by a polythene sheet to permit evaporation and isolate dust. After 2 weeks, pure carnallite crystals were obtained. The MCT detection parameters were: voltage150 KV; current 0.20 mA; distance of focus and object to the detector are 850 mm and 817.94 mm; distance of focus to object was 32.06 mm. CT data were reconstructed as 1024×1024 16 bit grayscale images per scan. The relative density value used in manuscript was calculated according to the density is proportional to the material gray scale (G_m).the formula as following:

$$\rho_R = \frac{G_m \times 1.602\ \mathrm{g/cm^3}}{328}$$

2. Sample sit description

The Qarhan salt lake, located in Qaidam Basin, Qinghai province, northwest China, contains abundant potassium, sodium, magnesium and lithium salt deposits. The Qarhan salt lake is the most important and the largest potash fertilizer base in China. Qinghai Salt Lake Industry Group Co. Ltd is the biggest potash fertilizer production enterprise in Qarhan. The reverse flotation cold crystallization strategy was implemented to produce millions of tons potassium chloride fertilizer per year using carnallite as raw material in Qinghai Salt Lake Industry Group Co. Ltd. Taking advantage of local abundant solar and wind energy resources, carnallite was harvested by evaporating salt lake brine. The brine evaporation flow chart and the main chemical components (w%) of brine in the solar carnallite pond was shown in Fig. S1.

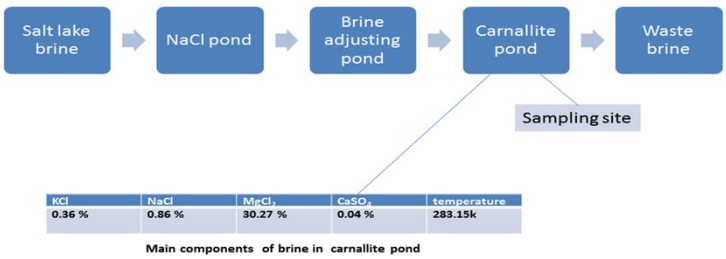
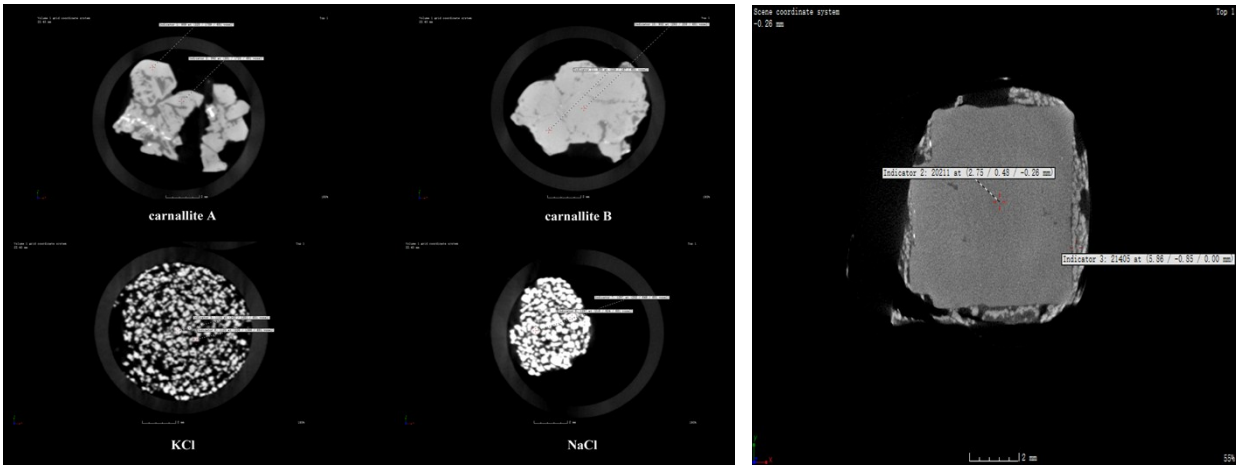


Fig.S1 the flow chart of carnallite production

3. The relationship between mineral density and gray scale

In Fig.S2, carnallite A was the pure carnallite we crystallized in our lab, Carnallite B was the solar carnallite collected from Qarhan salt lake; The MCT data was analyzed using VG Studio Max 2.2.



a (Voltage 180 KV; current 0.40 mA) b (Voltage 120 KV; current 0.40 mA)

Fig.S2 **the relationship between image gray scale and matter densit**

Because of larger compact gypsum crystals were really rare and hard obtained while the common pure gypsum particles were too fluffy to analyze by MCT. So we obtain its calibrated gray scale value by crystallizing a layer of pure gypsum on the surface of a large pure NaCl crystal. A pure NaCl crystal was put into NaCl saturated solution and then pure $CaSO_4 \cdot 6H_2O$ powder were added into until $CaSO_4$ was over saturated, standing for 12 hours at 20℃. The Crystal with a gypsum layer on its surface was scanned by MCT, and then the pure gypsum gray scale was obtained. The gray scale value of each pure crystal and the gray scale ratio between pure crystal with pure carnallite were provide in table 1.

Table 1 Gray scale value and the gray scale ratio between pure crystals with pure carnallite

Material	KCl	NaCl	$CaSO_4 \cdot 2H_2O$	$MgKCl_3 \cdot 6H_2O$	$MgKCl_3 \cdot 6H_2O$（B）
Gray scale	1114	1297	1373*	940.5	966
G.S. ratio with pure carnallite	1.18	1.38	1.46	1.00	1.03

4. Impurity composition

We analyzed the MCT data using VG Studio Max 2.2, and 1554 impurity particles which gray scale value was more than 330 were found in our specimen. MCT data analysis shows that the mean gray scale value of specimen was 328. Therefore, it was defined that the specimen gray scale was 328. The gray scale ratio of 1554 impurity particles was calculated as $G_{(M)}$ /328 and the relationship between frequency with grayscale ratio was shown in Fig.S4

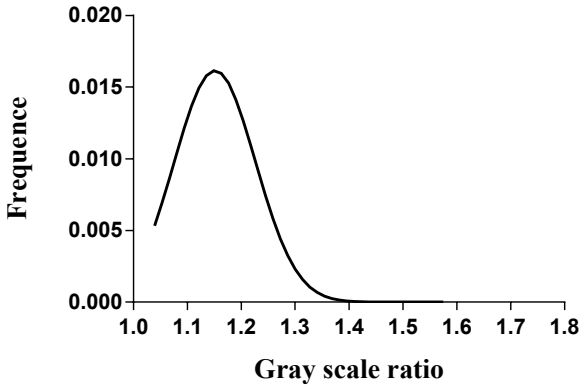


Fig.S3 Image of impurities gray scale ratio and the presence frequence

As shown in Fig.S3, the range of impurities gray scale ratio distribution is 1.1-1.4. Only a few impurities have gray scale over than 1.4. According to the brine compositions and the gray scale ratio, we deduced the main compositions of impurities in crystal carnallite were KCl, NaCl and little $CaSO_4$.

The phase structure of carnallite and impurity particles were characterized by XRD, using a Rigaku D/max 2550VB/PC diractometer with Cu Kα (λ =0.154 nm) radiation as the incident beam. The diffraction peaks match well with the standard values of carnallite (JCPDS NO. 24-0869), halite (JCPDS NO. 05-0628) and sylvite (JCPDS NO. 41-1476)

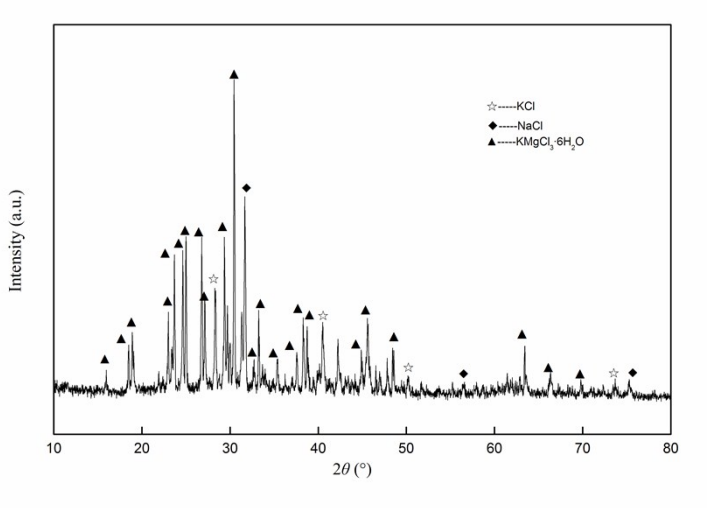


Fig.S4 XRD Pattern

The components of carnallite were analyzed by EDS (FALCON, voltage of 15 kV). The EDS survey spectra of the specimen indicated that the crystal main chemical composition was oxygen, chlorine, magnesium, potassium and sodium. The results obtained from EDS echo well to the conclusion we drawn by analyzing MCT data.

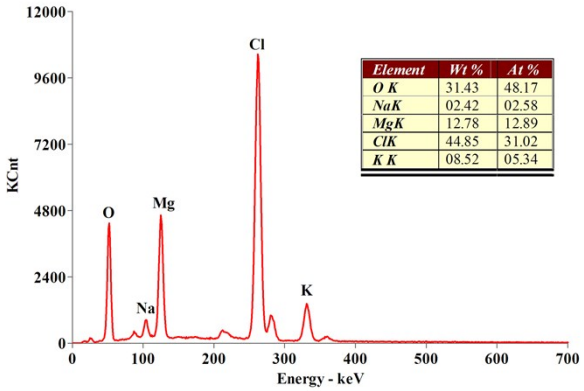


Fig.S5 EDS Pattern