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碳酸钙水泥：一种碳捕获、利用和储存（CCUS）技术

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摘　要:

>40MPa

关键词:

Calcium Carbonate Cement: A Carbon Capture, Utilization, and Storage (CCUS) Technique

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Abstract:A novel calcium carbonate cement system that mimics the naturally occurring mineralization process of carbon dioxide to biogenic or geologic calcium carbonate deposits was developed utilizing carbon dioxide-containing flue gas and high-calcium industrial solid waste as raw materials. The calcium carbonate cement reaction is based on the polymorphic transformation from metastable vaterite to aragonite and can achieve >40 MPa compressive strength. Due to its unique properties, the calcium carbonate cement is well suited for building materials applications with controlled factory manufacturing processes that can take advantage of its rapid curing at elevated temperatures and lower density for competitive advantages. Examples of suitable applications are lightweight fiber cement board and aerated concrete. The new cement system described is an environmentally sustainable alternative cement that can be carbon negative, meaning more carbon dioxide is captured during its manufacture than is emitted.

Keywords: Cement; Calcium carbonate; Vaterite

引言　　Worrell　　2030

2004

26.3GtCO2　　37%

1971　2004　　CO2

1.5%　30

1.6

Worrell

39,000,000Gt

Hanaoka

2020　　Oda

DNE21þ

550ppm

IEA　MARKAL

2050

IPCC

2.水中矿化过程

NH4Cl

CaCl2

NH3 NH3

NH4OH 40◦C

CSTR

11vol%

Fontaine Combes 20

CaCl2 Na2CO3 600 /

-

vaterite

3-13 NH4Cl

Combes

7% 70% 30%

3.分析和测试

3.1

Horiba LA-950V2

650nm 405nm LED

1.378

1.58

3.2 X

ARL QUANT'X X

950◦C 60

LOI

3.3 X

X'Pert Pro X

40 kV 30 mA Cu Kα1

λ =1.5406 Å 5-65◦2 θ 0.02◦

4 s Jade 9

MAUD

Rietveld QXRD

3.4

SU-6600 SEM

/

3.5

4 10 1 3

7 14

w/c 0.35 50 x 50 x 50 mm3

0.1M ASTM C305

CaO Ca OH 2

C2H2

Ca OH 2

Ca/Mg

/CaO

NH4Cl NH4 2SO4 NH4NO3

CO2

CO2

1.材料和方法

25wt%

S2- SO42-

NH4Cl Ca OH 2

ASTM C109 14 60
40 60 80◦C 95% 80◦C 7 3
1 4 1 4 10 80
60◦C
3 7 14 24
40 60 80◦C

105◦C 4
1 kN/s

4.结果

4.1 MgCl2 MgSO4 Mg(C2H3O2)2
15 4μm
D90 D10 19 11 μm SrCl2, Sr(C2H3O2)2
4% 0.4 μm
CSTR

001 15
001 vaterite
/
Nielsen

NH4Cl

5 讨论

NH4Cl 5.1
HCl NH3 HCl NH3 2500
HCl 95%
CaCl2 90wt% Ca(OH)2
>99 wt%
1 wt%

4.2

pH 12.4
/
-
/ 2019 5.1-6.4
35-60wt% CaO

40
3-13 3-13
40◦C 1

1

2.3

5.2

5.3

130

2.8 3.9 /

4.6 5.6 /

900◦C 1450◦C

3.9 /

92 /

3.57 /

39%

38% 88%

2019 175

/ 16

/ 56 CO2/GJ

200 CO2/

216 /

440

216

224

658 Ca

224

882

6 结论

40

3

80◦C 3

pH

参考文献

1. Gartner E, Hirao H. A review of alternative approaches to the reduction of CO2 emissions associated with the manufacture of the binder phase in concrete. Cem. Concr. Res. 2015; 78: 126–142.

2. Hargis CW, Telesca A, Monteiro PJ. Calcium sulfoaluminate (Ye'elimite) hydration in the presence of gypsum, calcite, and vaterite. Cem. Concr. Res. 2014; 65: 15–20.

3. Monteiro PJ, Clodic L, Battocchio F, et al. Incorporating carbon sequestration materials in civil infrastructure: A micro and nano-structural analysis. Cem. Concr. Compos. 2013; 40: 14–20.

4. Morse JW, Arvidson RS, Lüttge A. Calcium carbonate formation and dissolution. Chem. Rev. 2007; 107: 342–381.

5. Addadi L, Raz S, Weiner S. Taking advantage of disorder: Amorphous calcium carbonate and its roles in biomineralization. Adv. Mater. 2003; 15: 959–970.

6. Fontaine M-L, Combes C, Sillam T, et al. New Calcium Carbonate-Based Cements for Bone Reconstruction. Key Eng. Mater. 2005; 284–286: 105–108.

7. Combes C, Miao B, Bareille R, et al. Preparation, physical–chemical characterisation and cytocompatibility of calcium carbonate cements. Biomaterials 2006; 27: 1945–1954.

8. Hu Q, Zhang J, Teng H, et al. Growth process and crystallographic properties of ammonia-induced vaterite. Am. Miner. 2012; 97: 1437–1445.

9. Trushina D, Bukreeva TV, Kovalchuk MV, et al. CaCO3 vaterite microparticles for biomedical and personal care applications. Mater. Sci. Eng. C 2014; 45: 644–658.

10. Popławski D, Hoffmann J, Hoffmann K. Effect of carbonate minerals on the thermal stability of fertilisers containing ammonium nitrate. J. Therm. Anal. Calorim. 2016; 124: 1561–1574.

11. Bischoff JL. Kinetics of calcite nucleation: Magnesium ion inhibition and ionic strength catalysis. J. Geophys. Res. Space Phys. 1968; 73: 3315–3322.