Synthesis of a Si-based construction material for terrestrial and extraterrestrial construction under low temperature

The University of Tokyo   Sakai Yuya's lab   Pengcheng Qiu   https://ysakai.iis.u-tokyo.ac.jp/

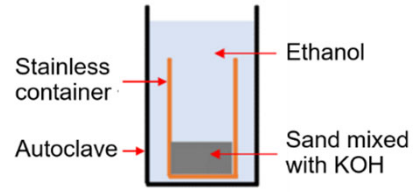
Background

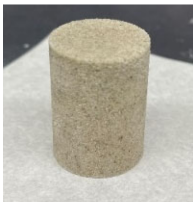
With global urbanization, the demand for concrete keeps increasing. However, concrete leads to high carbon emissions and faces the scarcity of raw materials like high-quality sand. Space exploration is accelerated globally and construction of the universe will be in the near further. Therefore, new construction materials with abundant raw materials that suitable for both terrestrial and extraterrestrial construction are needed. Although high-quality sand is lacked, low-quality sand (particle size < 250 μm) is abundant because it can hardly used for building materials. Moon sand is also one kind of low-quality sand. Consequently, we want to find one way to transform low-quality sand into construction materials directly. 110^{o}C was selected because it is the average day-time temperature on the moon.

Experimental sections $SiO_2 + C_2H_5OH \Leftrightarrow Si(OC_2H_5)_4 + 2H_2O$

Preparation

The sand was mixed with KOH, which was placed in a stainless container and the autoclave. Autoclaves were heated at 110°C for 6 days to get wet powder, which was hot-pressed under 105°C and 2.5 MPa for 1 min. The specimens were dried at 105°C for another 5 days, which were then sintered at 800°C for 6 h..

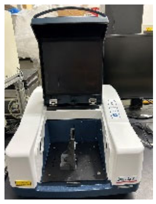




Characterization

The porosity of the specimens was measured using the Archimedes principle. The compressive strength was measured by a universal testing machine. The crushed specimens were then investigated by XRD, FT-IR, SEM and ^{29}Si MASS NMR. Waste solution was recycled vis rotary evaporator.

XRD



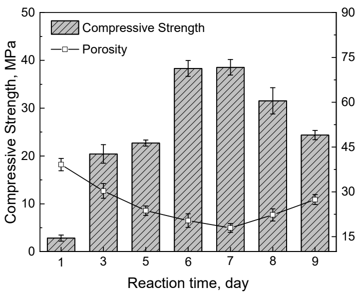
FT-IR

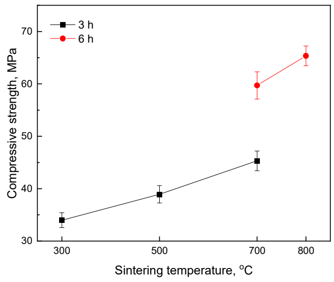
SEM

Results

Compressive strength and porosity

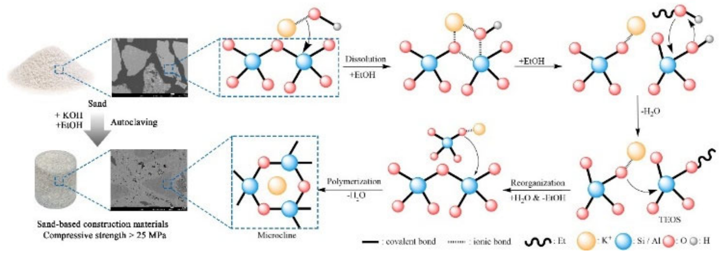
Appropriate KOH content, EtOH concentration, reaction time, hot-press and sintering conditions can improve the compressive strength (up to **65 MPa**).





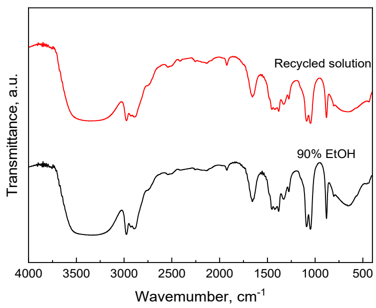
Hardening mechanism

- Formation of new crystals due to the dissolution and reorganization of Si-O-Si and Al-O-Al. They make the structure more homogenous and lower the porosity.
- Formation of appropriate TEOS, which is a good consolidate, which can function as glue to increase the strength.



Waste solution recycling

Waste solution was recycled through the rotary evaporator. The density of recycled solution is about **801.18 kg/m^3** and recycle rate is about **66.40%.**



Carbon emissions calculation

Materials & Related process	Carbon emissions /kg CO_2 eq	Percentage /%
Sand	3.30	1.68
Ethanol	65.26	33.32
KOH	37.98	19.39
Tap water	0.00050	0.00
Transportation	1.07	0.55
Construction electricity	88.27	45.06
Summary	195.88	100.00

The total carbon emission is **196 kg CO_2** eq after recycling waste solution (Recycle rate: 66.4%), could be further reduced to **110 kg CO_2 eq** if using heat waste.

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