CSSC 中国船舶集团有限公司第七一一研究所
SHANGHAI MARINE DIESEL ENGINE RESEARCH INSTITUTE

Feasibility Study of Immobilized Carbonic Anhydrase Synthesis Technology and Its Application in the Carbon capture Field

1.SMDERI Introduction

2. Development of carbon capture technology

3. Research on new carbon capture method

4. Conclusions

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Deputy Director, Environmental Equipment Division, Shanghai Marine Diesel Engine Research Institute

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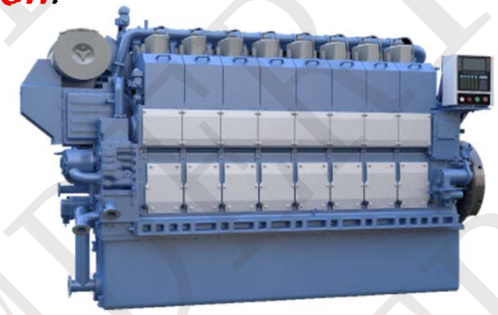
1

SMDERI Introduction

SHANGHAI MARINE DIESEL ENGINE RESEARCH INSTITUTE

Founded in 1963, **SMDERI** is the only national research institute of marine diesel engine in China, from which derive **six business sectors**. With more than **3000 employees**, its revenue is approx. **USD 950 million**.



Diesel/Gas Engine

Stirling Engine

Power System Integration

Ship Automation System

Energy Equipment

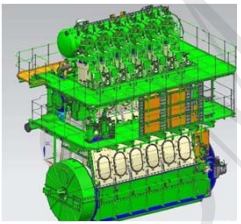
Marine Equipment

MARINE EQUIPMENT

Focusing on the two segments of energy upgrading and emission control, we carry out R&D, design, integration and sales of technologies and products.

Energy Upgrading

front end

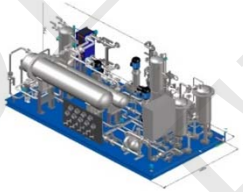


rear end

Emission Control

LNG Sub-cooler

FGSS



Methanol LFSS

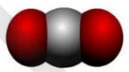
Ammonia LFSS

Diesel fuel → LNG → Methanol → Ammonia

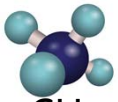
NOx

SO_2

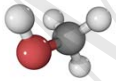
PM



CO_2



CH_4



CH_3OH

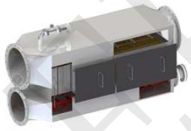
HCHO

NH_3

N_2O

SCR

Scrubber

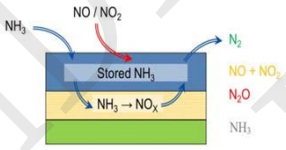


DPF: PM

CCS

MOC

DPF



AEC

MARINE EQUIPMENT

Since entering the global Scrubber & SCR market in 2016, SMDERI has cooperated with world-renowned shipping companies, shipyards and engine makers in after-treatment product and fuel supply system.

Shipowners

EVERGREEN
msc
COSCO SHIPPING
T.S. LINES
招商局集團 CHINA MERCHANTS GROUP
山东海运股份有限公司 SHANDONG SHIPPING CORPORATION
OOCL We take it personally
PIL
MDM MARAN DRY MANAGEMENT INC.
DYNACOM
NYK LINE NIPPON YUSEN KAISHA
K LINE KAWASAKI KISEN KAISHA, LTD.

Engine Makers

WÄRTSILÄ
DAIHATSU
WIN GD
MAN
MTU Aero Engines
CAT
Cummins

Shipyards

SAMSUNG HEAVY INDUSTRIES
沪东中华造船（集团）有限公司 Hudong-Zhonghua Shipbuilding (Group) Co., Ltd.
CSSC 上海外高桥造船有限公司 SHANGHAI WAIGAOQIAO SHIPBUILDING CO.,LTD.
揚子江船業集團公司 YANGZIJIANG SHIPBUILDING GROUP LTD.
江南造船集团有限公司 Jiangnan Shipyard(Group) Co.,ltd
COSCO SHIPPING
DSIC
NTS
HRDD 上海華潤大東船務工程有限公司 HUARUN DADONG DOCKYARD CO., LTD.
CIMC RAFFLES

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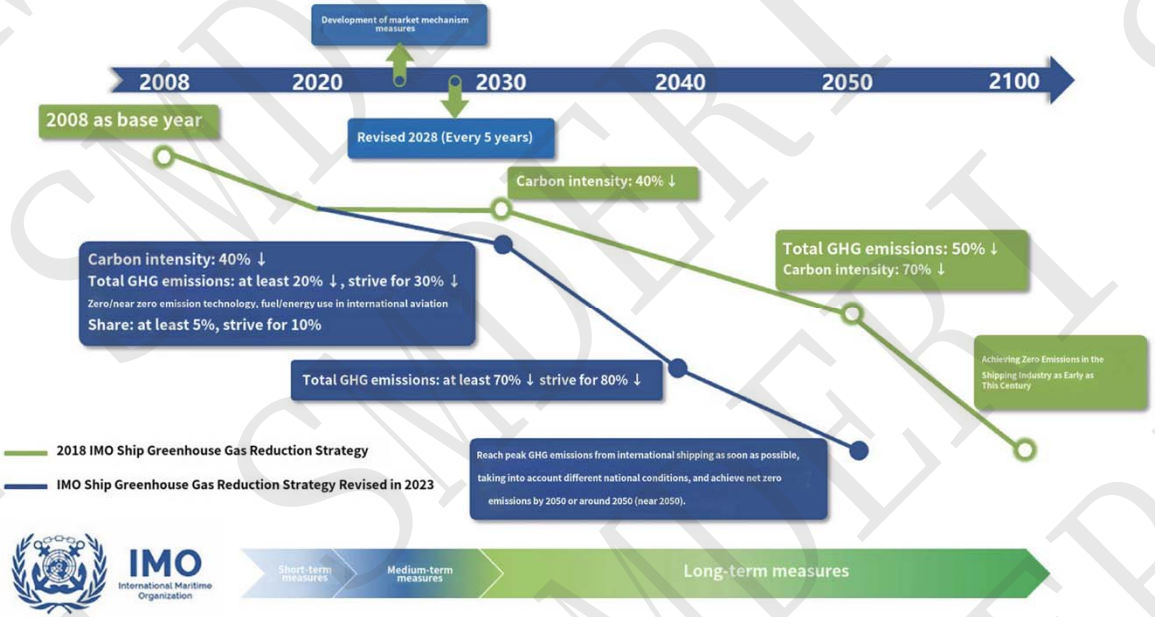
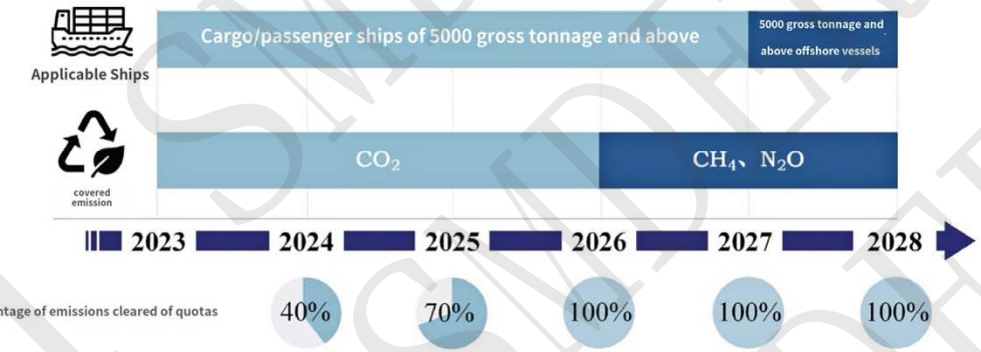
Research background

2023 IMO GHG strategy



EU ETS



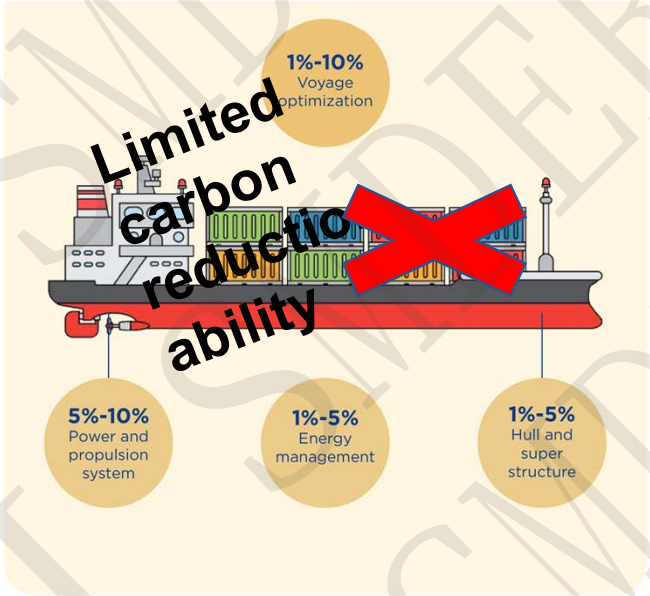
IMO

IMO GHG strategy

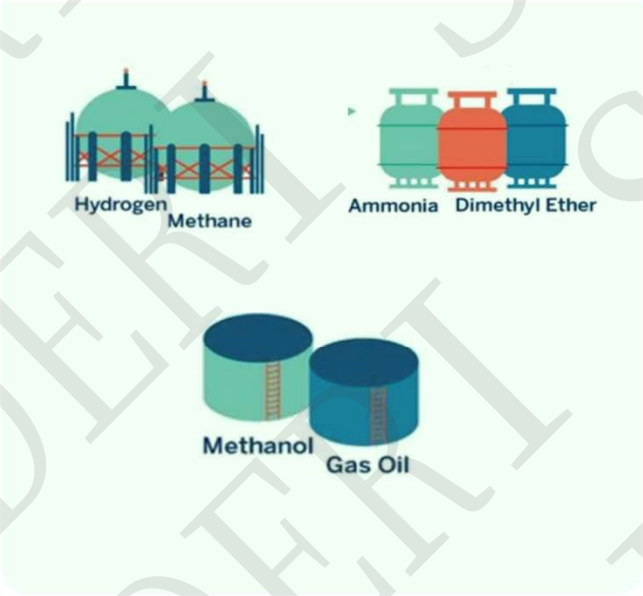
European Commission

EU ETS

Efficiency Improve

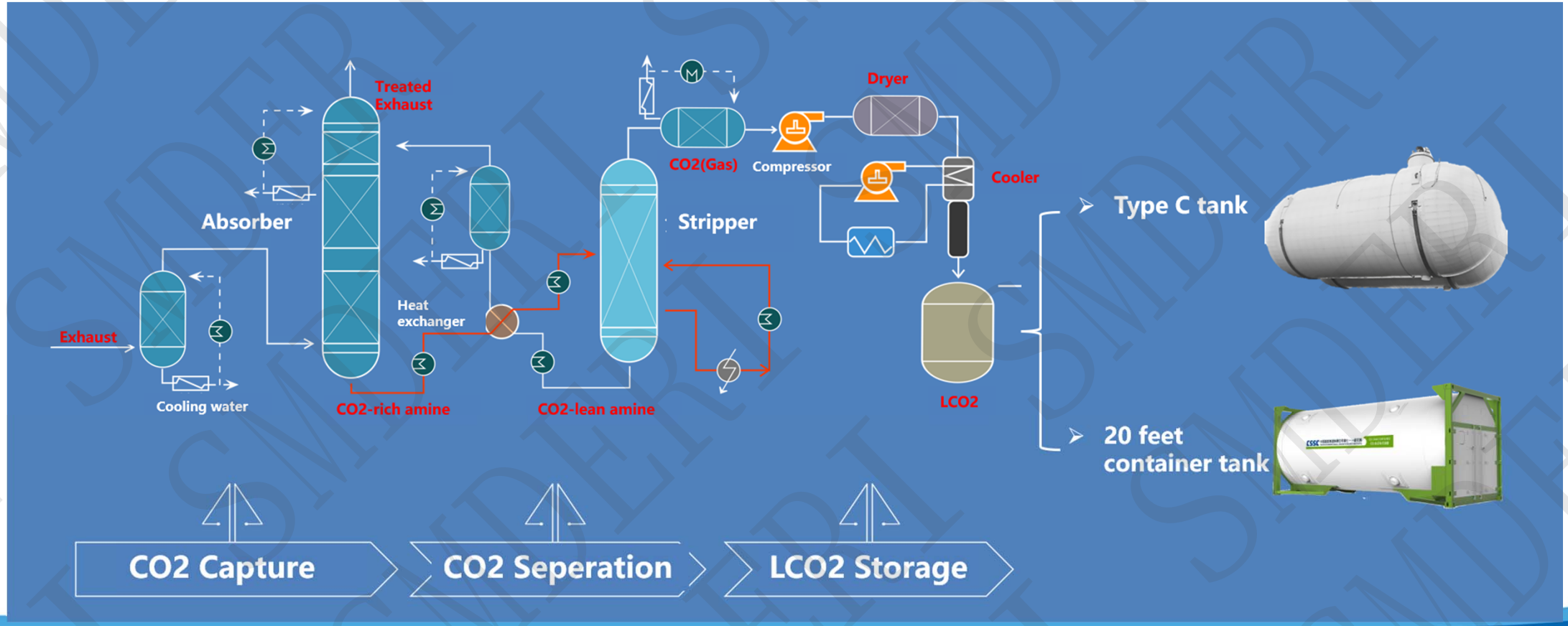


Green alternative fuel



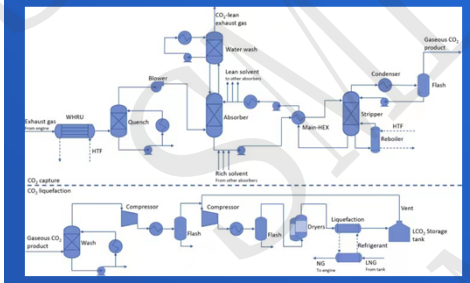
Carbon Capture

- Max. Carbon Reduction Rate can exceed **80%**



Developing History

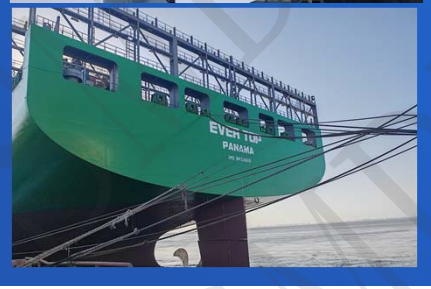
2018
R&D started



2019-2020
Prototype, Testing

2021-2022
AiP, Product development

2023-2024
First project delivery



Technical Advantages

❖ New absorbent

New absorbent with high efficiency, dedicated for vessels, **max. capture efficiency over 80%.**

❖ Low-energy desorption

Waste heat utilization, low-temperature desorption, **steam consumption reduced by 8%.**

❖ Supercritical CO2 refrigeration

Supercritical CO2 refrigeration with higher heat transfer efficiency and refrigeration performance, **power consumption reduced by 5%**

Product Advantages

❖ Marin emission reduction One-stop solution

Multi-pollutants emission reduction design, save vessel space

❖ Modular system design

Modular design with compact size, **easy for installation and save vessel space.**

❖ Customized carbon capture rate

Customized carbon capture rate to best suit your carbon emissions and needs.

OCCS DEVELOPMENT

First prototype of CO2 capture and storage system for vessel in China

Class Certifications

- Based on a low-speed engine test bench, first domestic carbon capture system for vessel was developed.
- Class Certifications by Class such as CCS, LR, BV, DNV, etc.

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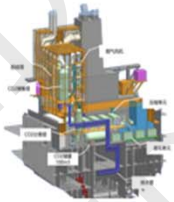
OCCS FOR 14,000TEU CONTAINER VESSEL

Design, Class approval — 2023.1-4



Manufacturing — 2023.4-10

Delivery started, yard pre-fabrication — 2023.10

Vessel arrived, installation started — 2023.11.15

Sea trial and vessel delivery — 2024.1.15-1.18

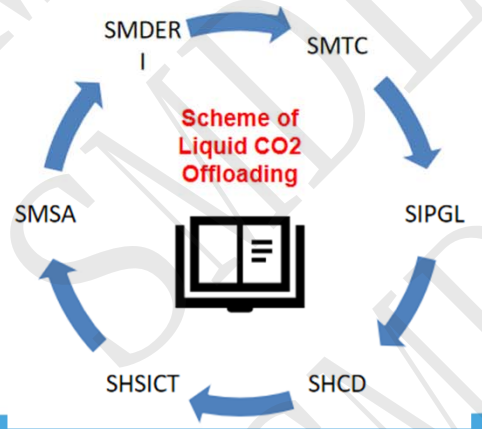
World's 1st Full-process OCCS

Notation: SCCS-Full

LCO2 OFFLOADING

Scheme of Offloading : Multi-party collaboration

- SMTC: Shanghai Municipal Transportation Commission
- SMSA: Shanghai Maritime Safety Administration
- SHCD: Shanghai Customs District P.R.China
- SHSICT: Shanghai Shengdong International Container Terminal



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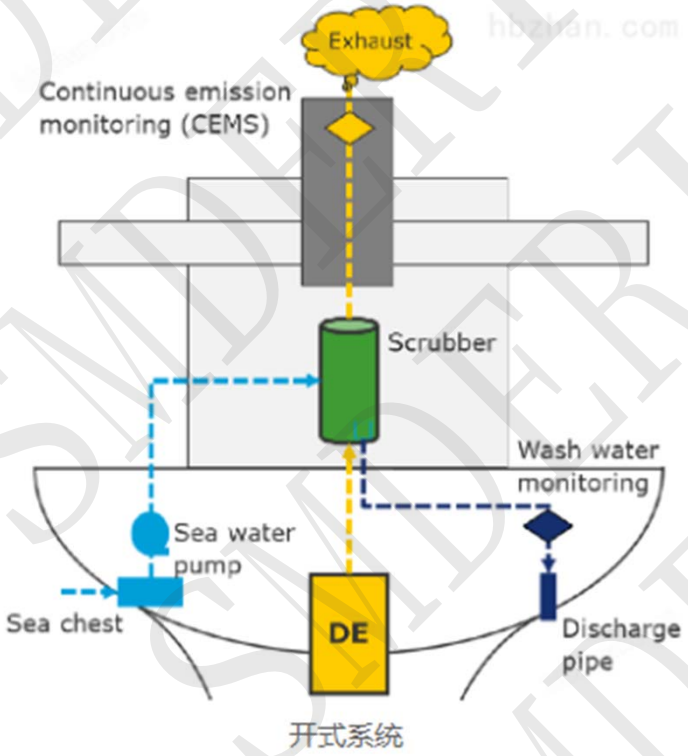
Research on new carbon capture method

- Using seawater absorbs carbon dioxide



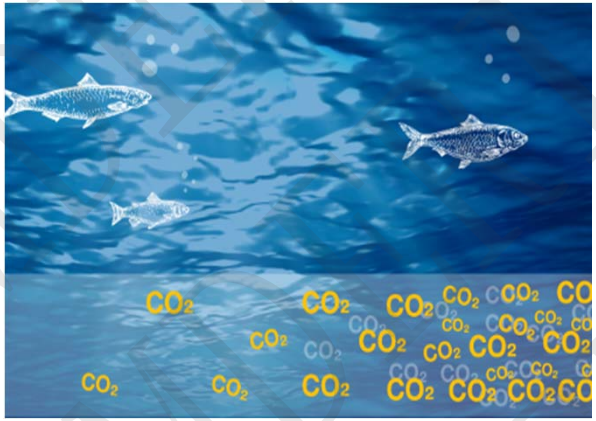
Open seawater desulphurization system

Open seawater decarbonization system ?

$SO_2+H_2O \rightarrow H_2SO_3$

$2H_2SO_3+O_2 \rightarrow 2H_2SO_4$

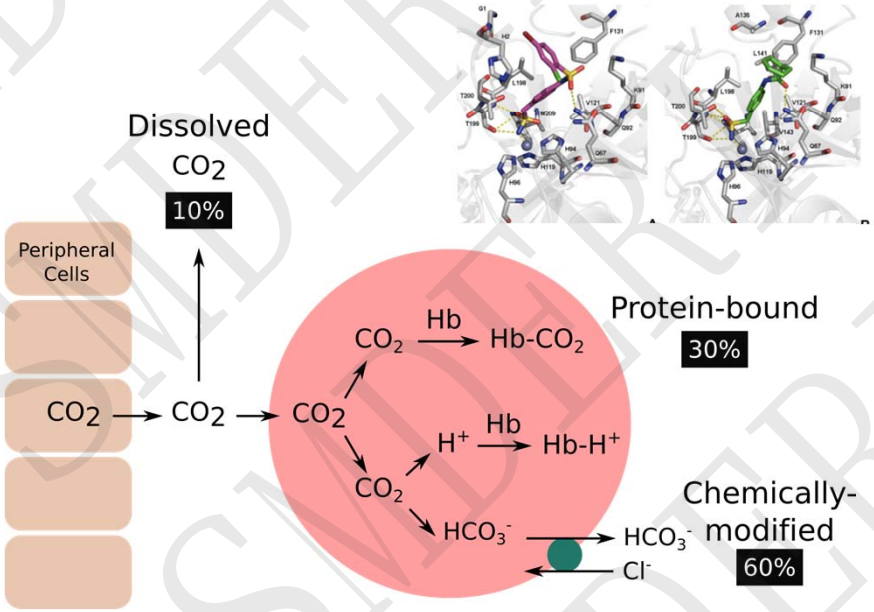
$Ca^{2+}+SO_4^{2-} \rightarrow CaSO_4$



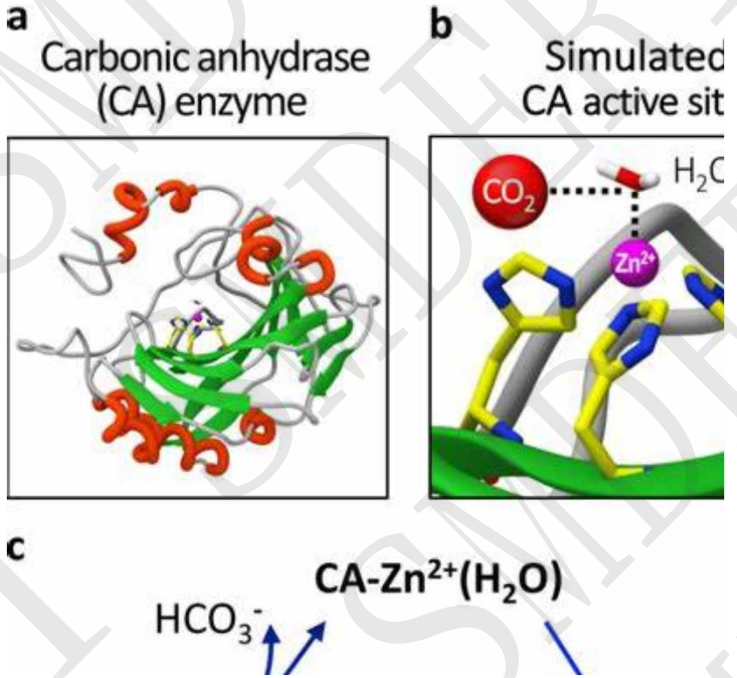
$CO_2+H_2O \rightarrow H_2CO_3$?

- The carbonic anhydrase (CA)-catalyzed reversible hydration reaction of CO2 is the most efficient CO2 hydratase catalyst discovered to date.

10^8 ↑



Catalytic center of carbonic anhydrase



Mechanism of CA-catalyzed CO2 hydration reaction

Building test beds

Carbonic anhydrase preparation platform and gas-liquid absorption bench were constructed

Catalyst Preparation Platform

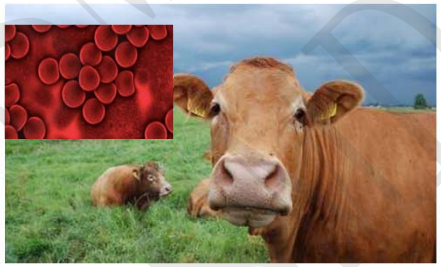
Catalyst Coating Platform

Compact Test Stand

Medium Test Stand

Key technology 1: Research on carbonic anhydrase gene sequence screening and modification technology suitable for marine environment

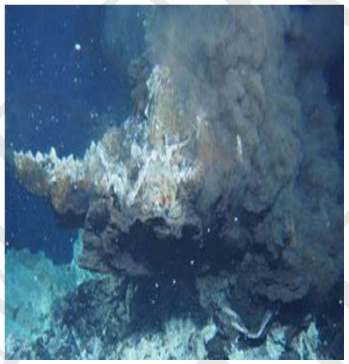
- Research objective: CAs are stable and maintain high activity at 40-60°C, in seawater and alkaline environments;
- Research Method: Screening of CA sequences from extreme environments such as craters, thermophilic bacteria, and deep-sea sources for compliance.



Bovine erythrocyte

Crater

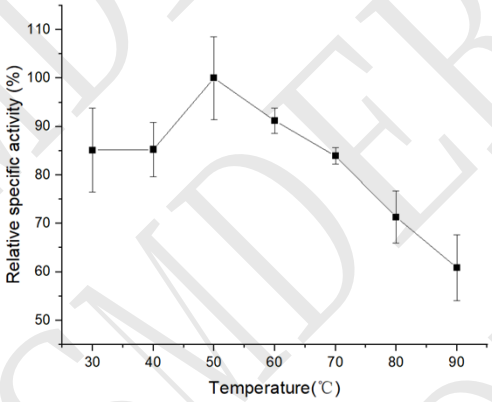
Thermophilic bacteria

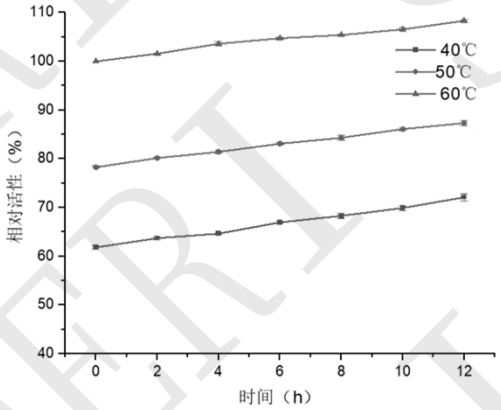


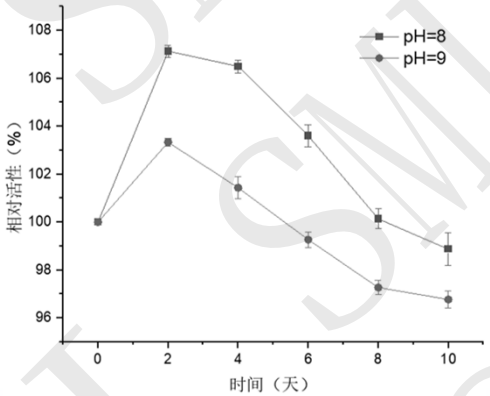
Deep-sea

Key technology 1

- The thermophilic source SazCA was finally selected for plasmid construction and recombinant protein expression, and the results showed that it had good stability.

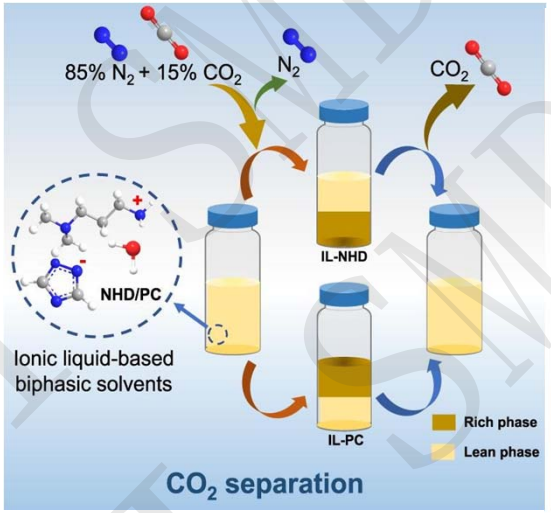




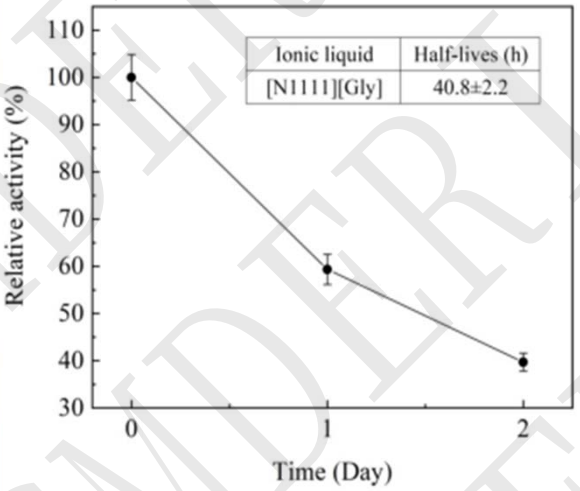


Optimum temperature and stability of recombinant proteins

50°C
pH=8~9



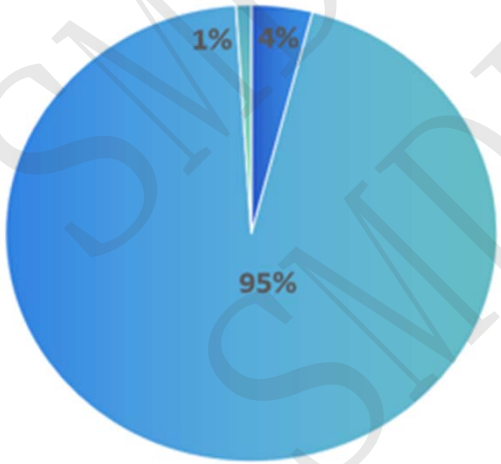
Ionic Liquid CO2 Capture Schematic

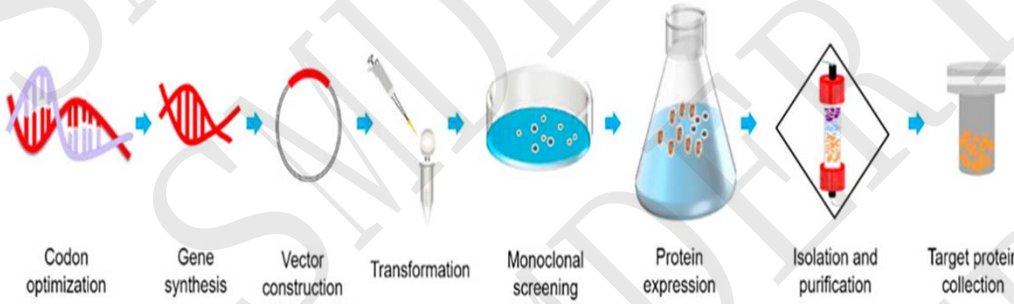


Stability of carbonic anhydrase in [N1111] [Gly

Key technology 2: Research on low-cost and batch carbonic anhydrase strain culture and protein synthesis technology

- Research objective: The cost of CAs preparation and purification is less than $70/g;
- Research Method: Simple, efficient and low-cost batch preparation of carbonic anhydrase by incorporating molecular chaperones and optimizing bacterial culture conditions.



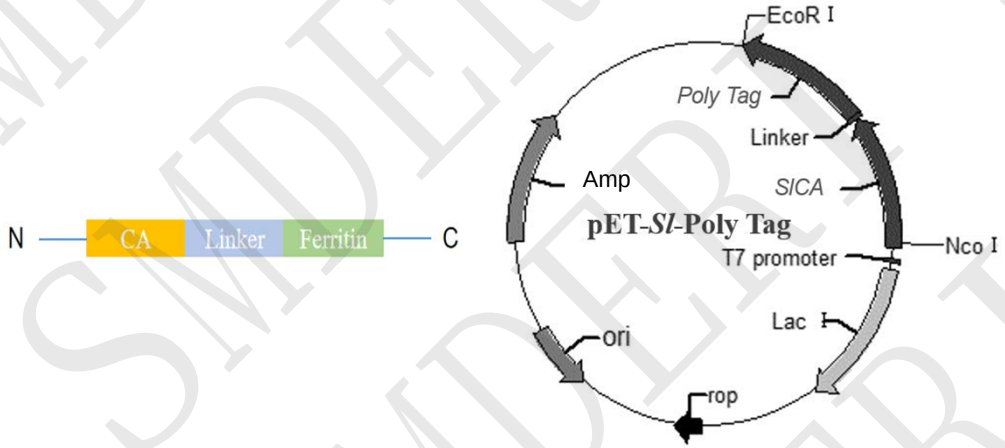


Protein preparation process

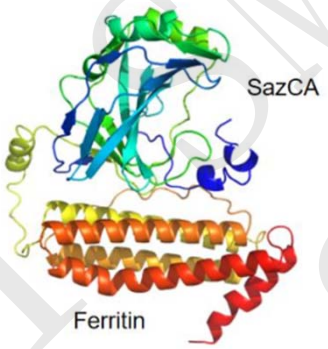
General Catalyst Costs:

Purification costs: 95%
Protein Expression and Extraction Costs: 4%
Other costs: 1%

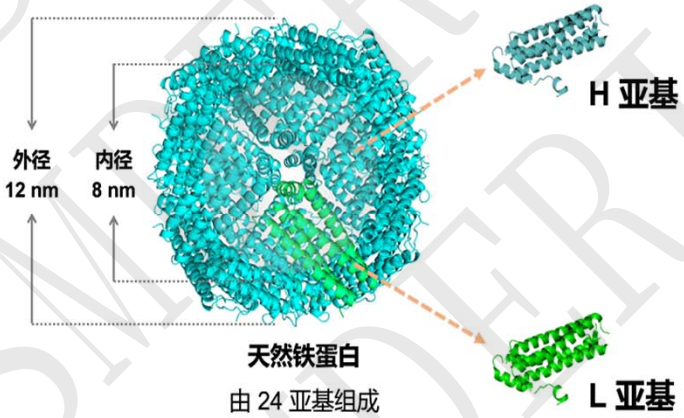
- Introducing ferritin-tags and performing plasmid construction to form CA and ferritin tag chimeras (SazF).



Schematic diagram of a recombinant CA plasmid (pET-SazCA-Ferritin)



Tertiary structure of recombinant CA



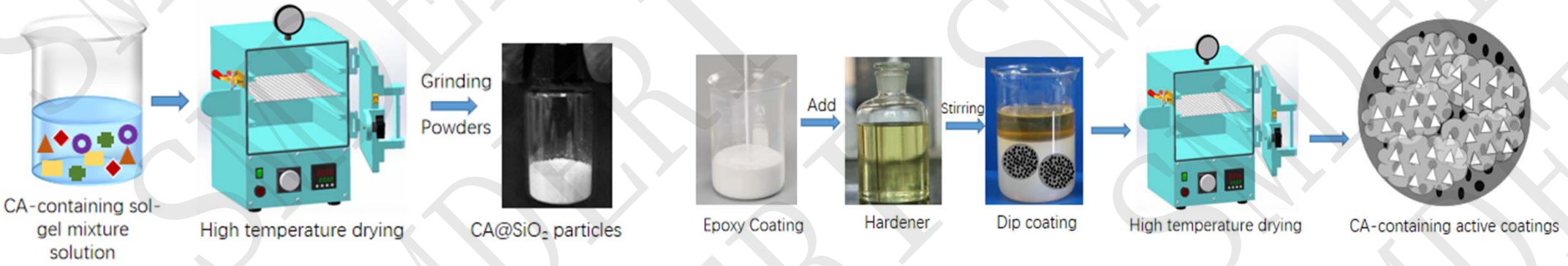
Schematic structure of natural ferritin (the protein shell and the internal iron core)

Key technology 3: Research on carbonic anhydrase and ship filler linkage coating technology based on embedding immobilization

- Research objective: To find a highly active and stable immobilization coating method suitable for CA and to achieve reusability of the enzyme;
- Research Method: CA immobilization coating was successfully achieved by a two-step method based on the sol-gel method.

Ⅰ: Generation of $CA@SIO_2$ gel particles

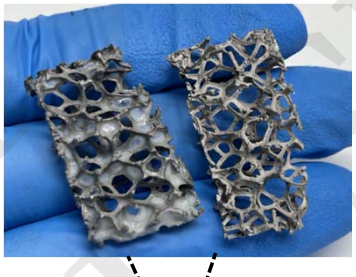
Ⅱ: Coating and drying of $CA@SIO_2$ gel particles

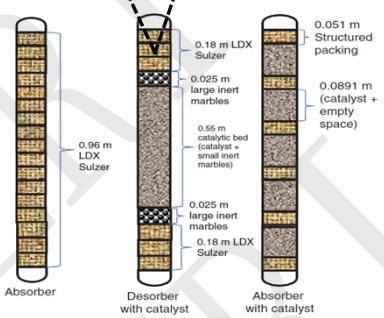


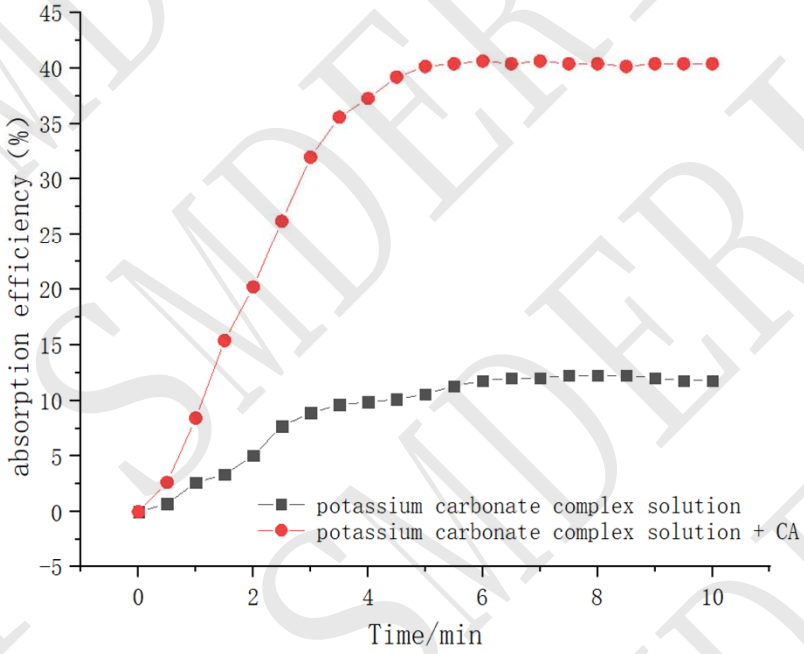
Schematic diagram of carbonic anhydrase immobilization and coating

Key technology 3

- The addition of coated CA significantly increased the CO_2 absorption efficiency of the seawater , and the efficiency increased to **40.4%.**







Next Steps: Optimizing coating conditions to improve coating loading

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Conclusions

Conclusion

- Besides alternative fuel, Carbon capture is a feasible method to reduce the carbon dioxide
- This study innovatively proposes a CO_2 seawater capture technology based on biomimetic method;
- CA is a good catalyst that promote the reaction of CO2 with seawater. The addition of coated CA significantly increased the CO_2 absorption efficiency of the seawater and the efficiency increased to **40.4%.**
- In the next phase，we will focus on improving the coated enzyme activity and exploring the optimal conditions for its absorption in the absorber tower.

Thanks