Supporting Information

CO_2 Capture by Dry Alkanolamines and an Efficient Microwave Regeneration Process

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Experimental

Recycling of perfluorinated SiO_2 nanoparticles: CO_2-loaded DA_f powder was dispersed in 20-30 mL ethanol in a 50 mL centrifuge tube to dissolve the alkanolamines/carbamate salts. The mixture was vortexed for approximately 10 min and then centrifuged at 3500 rpm at room temperature for 20 min, after which the particles were collected and re-dispersed in ethanol for at least 3 times. A recovery rate of approximately 75-80 wt% was obtained for the recycling process.

Instrumentation

Transmission Electron Microscopy analysis was performed with a Philips CM300 FEG instrument at 300 kV.
Optical microscope images were obtained with an Olympus BX51 microscope.
Brunauer-Emmett-Teller (BET) analysis was performed with a Micromeritics ASAP 2020 Surface Area and Porosity Analyzer.
Thermogravimetric Mass Spectroscopy (TG-MS) analysis was performed using a Netzsch TG 209 F1 and a Netzsch QMS 403C instrument, from 30 °C to 120 °C under 20 mL/min of nitrogen gas at a heating rate of 5 °C min^{-1}; the sample was subsequently heated isothermally at 120 °C for 30 min (total heating time is approx. 48 min).
The flow rates of CO_2 and argon purge gas were measured with a HP 220-1171-E 58 flow meter.
Regeneration of alkanolamine sorbents by dielectric heating was carried out using a Milestone StartSYNTH Microwave Synthesis Labstation.
The energy consumption by hotplate heating was measured using an Ecoplug BS1363 wattmeter.
Liquid surface tensions were measured using a Biolin Scientific Sigma 701 Force Tensiometer with a du Noüy ring. The average values of 10 measurements are recorded in Table S1.
Cryo-SEM of DA_f was performed on a Zeiss EVO60 Scanning Electron Microscope equipped with a Quorum PP3010T Cryo-SEM Preparation System. Samples were frozen with liquid nitrogen prior to loading into the cryo-SEM preparation system and sputter coated with platinum prior to imaging. DA_f size measurements were performed by measuring the diameters of 250 DA_f particles to obtain their average diameters and a standard deviation.
Dynamic Light Scattering (DLS) studies were performed with a Brookhaven ZetaPlus Zeta Potential Analyzer, to determine the size distribution profile of unmodified fumed silica

particles *versus* perfluorinated fumed silica particles after dispersing them in ethanol. The mean values of 5 measurements for each sample are recorded in Table S2.

The viscosity of alkanolamines before and after CO_2 absorption were measured with a Discovery Hybrid Rheometer 3. The viscosities are recorded in Table S3.

DA_f preparation was performed with a coffee whisk from the Daiso supermarket.

Digital photographs were taken using a Sony NEX-7 camera.

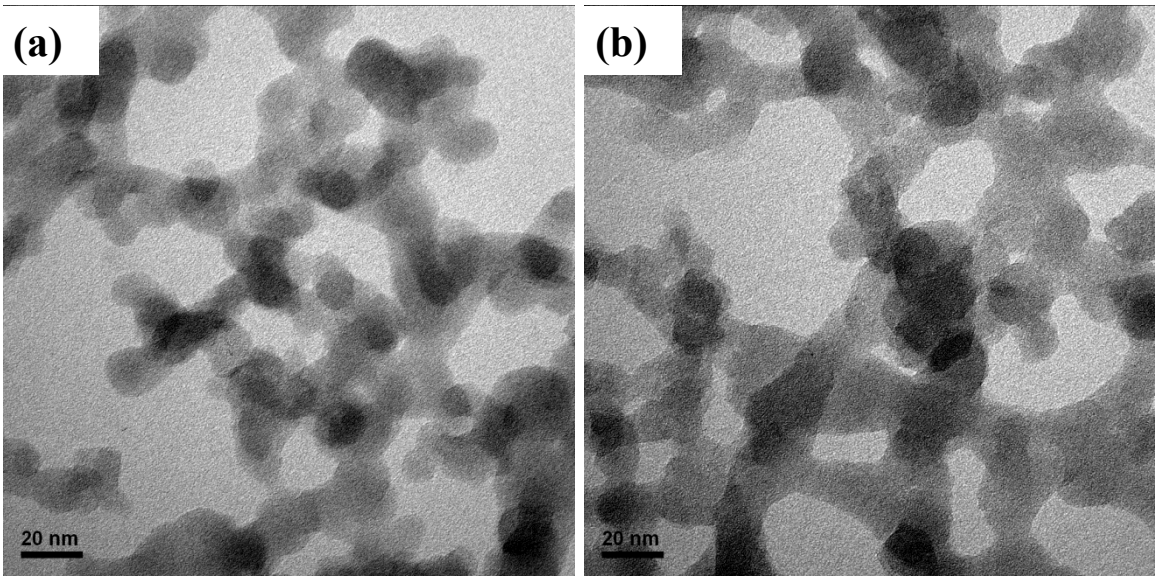


Figure S1. TEM images showing the aggregation of the primary particles for (a) untreated fumed silica particles and (b) perfluorinated fumed silica particles.

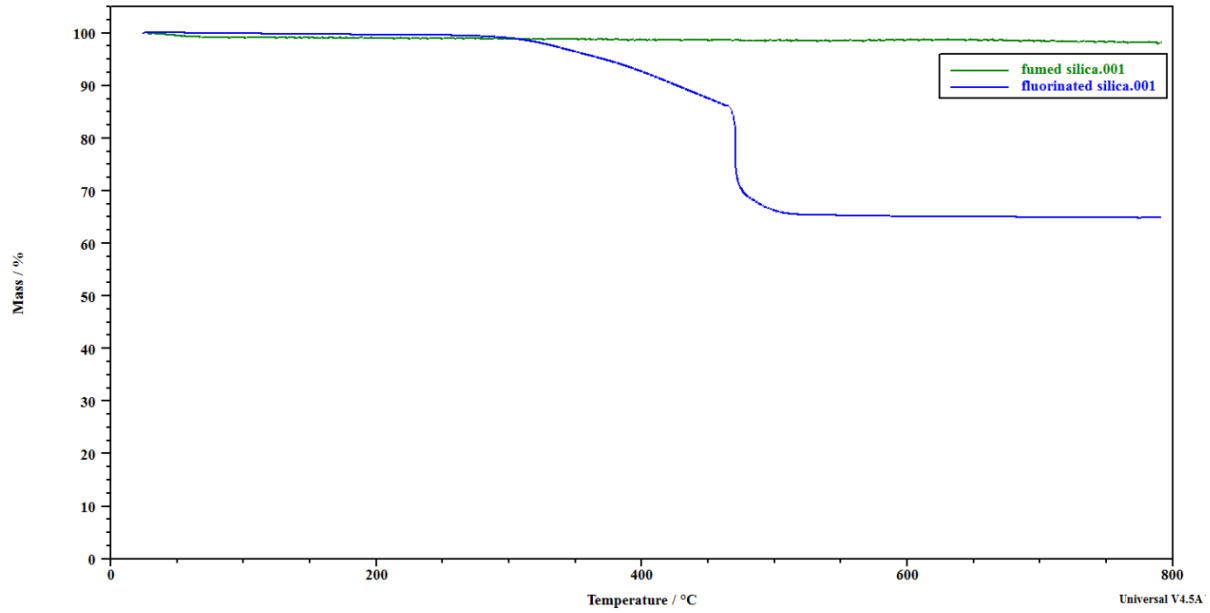
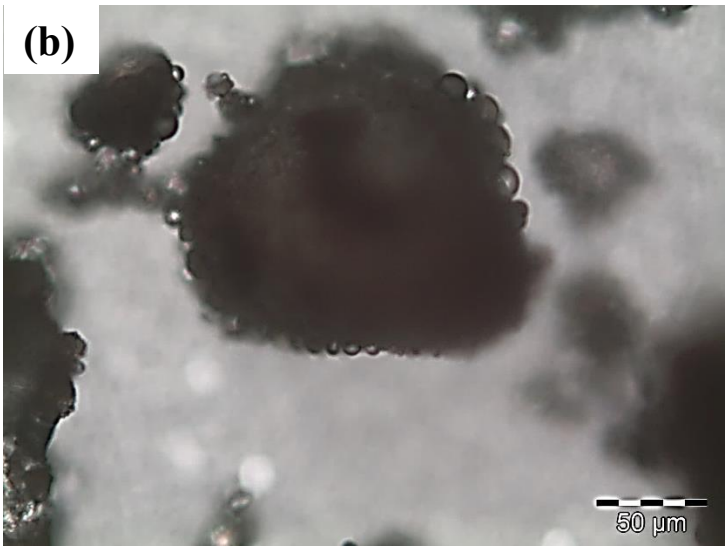
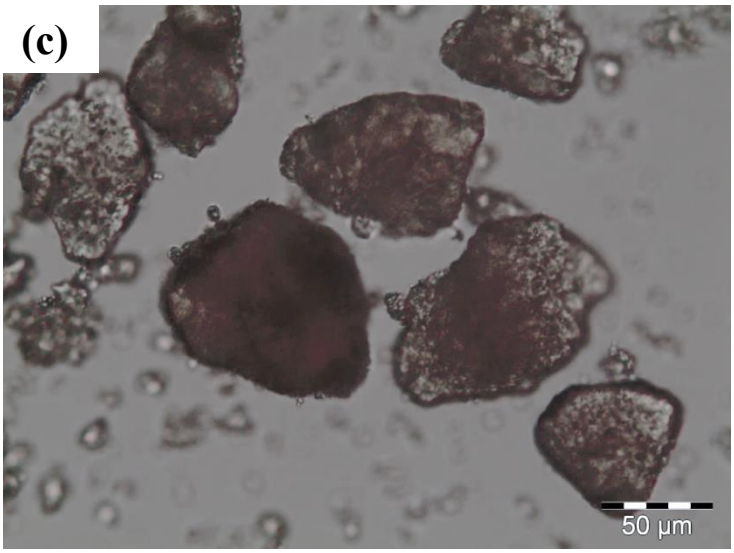


Figure S2. TGA graph of perfluorinated silica particles (green) and untreated silica particles (blue), where the y-axis shows the percentage of initial mass. The TGA analysis was run with 40 mL/min of nitrogen gas as balance gas and 60 mL/min of air as sample gas.


(a)


(b)
50 µm


(c)
50 µm

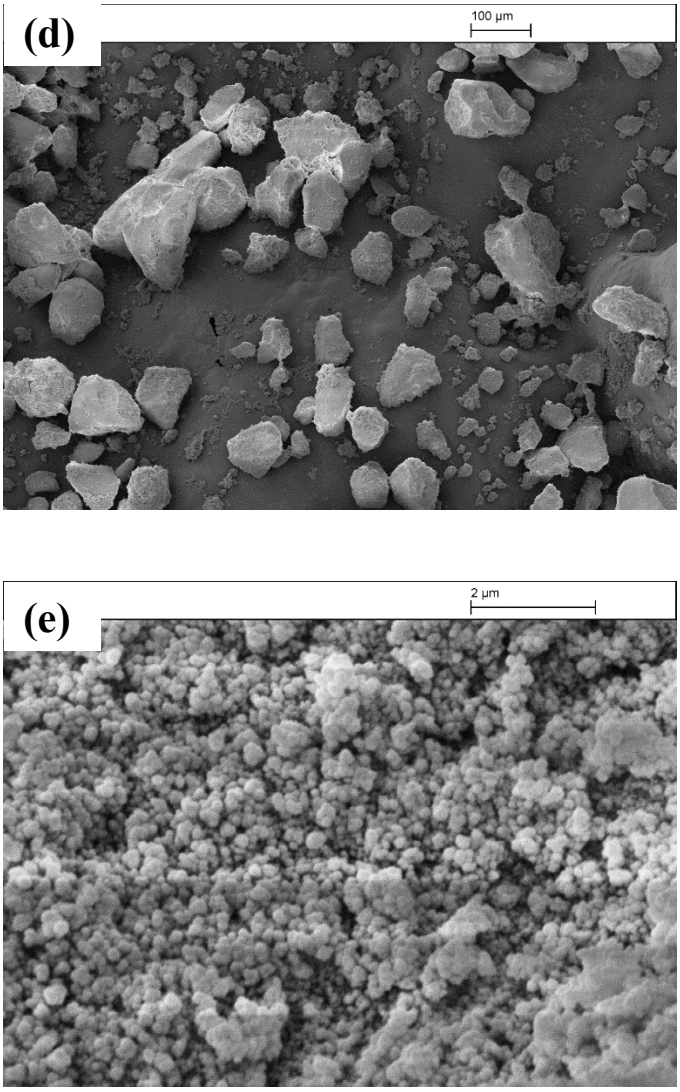


Figure S3. (a) Photograph of the coffee whisk used for the dry powder formation (approximate speed of 1000 rpm; white arrow represents 2.2 cm), (b) optical microscope image of dry MEA (c) optical microscope image of dry DEA, (d) cryo-SEM image of dry DEA. Samples were kept frozen on a nitrogen-chilled stage during the imaging process, (e) close up cryo-SEM image of surface of DEA droplet showing the silica particles on the surface.

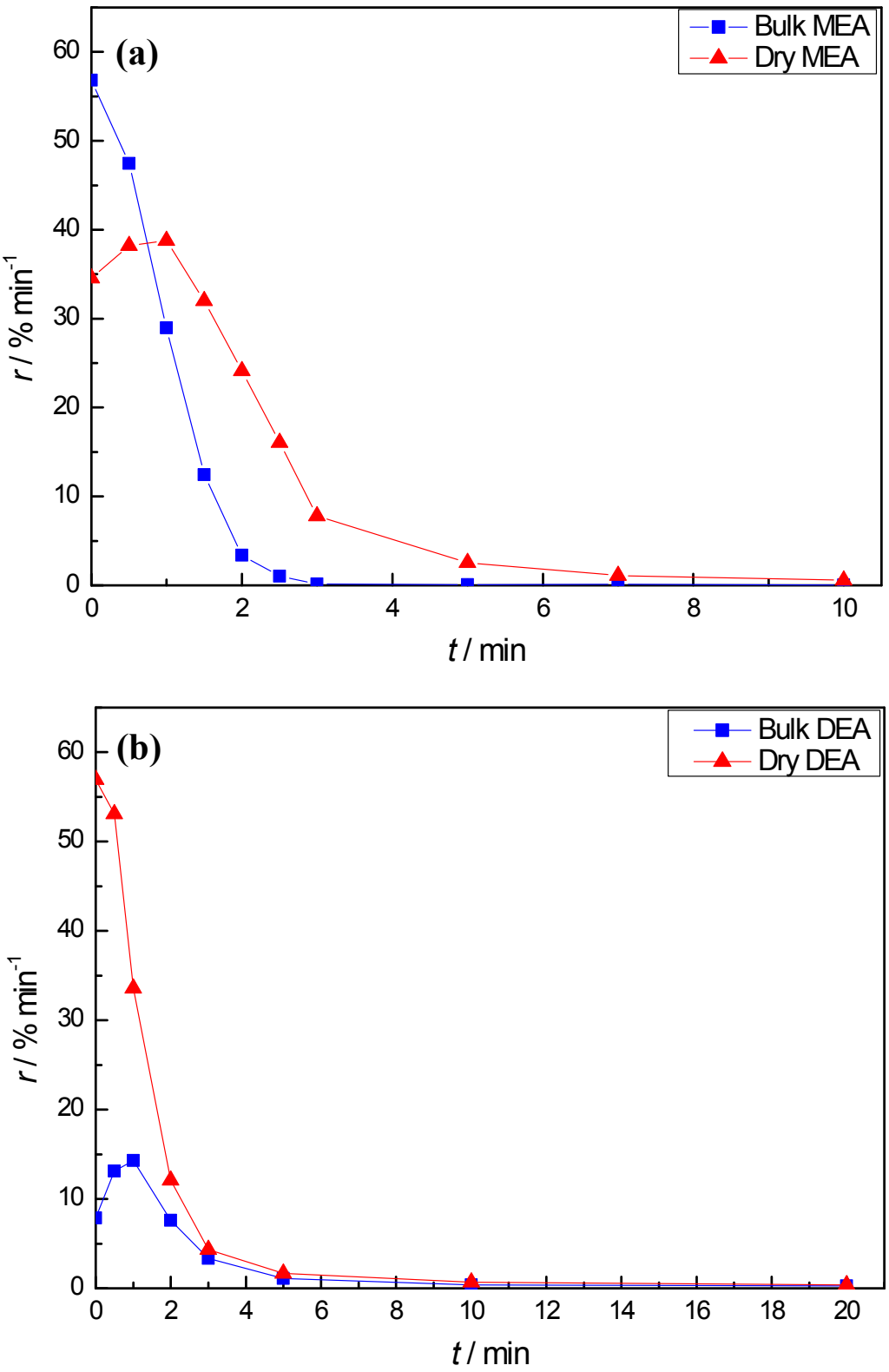


Figure S4. Variation of the first derivative of the CO_2 absorption profile with time for (a) MEA and (b) DEA which quantify the rate of CO_2 absorption.

Table S1. Surface tensions of tested liquids at 24.6 °C.

Liquid	Surface tension/mN m^{-1}
Ethanolamine	47.3
Diethanolamine	47.5
Water	70.7

Table S2. Average aggregate sizes of particles used.

Sample	Effective diameter/nm
Unmodified fumed silica	367
Perfluorinated fumed silica	282

Table S3. Viscosities of liquid absorbents at 25 °C at a shear rate of 10 s^{-1}.

Sample	Viscosity/cP
Neat MEA	61
MEA with 61.6% of maximum CO_2 absorption[a]	1370
Neat DEA	567
DEA with 21.7% of maximum CO_2 absorption	1481

[a]The maximum CO_2 uptake by alkanolamines (in the absence of water) was calculated by assuming a reaction mole ratio of 2:1 alkanolamine to CO_2.