Nanocomposite material like advanced sorbent materials for carbon dioxide capture

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ABSTRACT

In this work carbonized rice husk was used as carbon-based solid matrix in the preparation of composite materials modified with Fe_3O_4 particles. Aim of this study is to exploit the advantages and shortcomings of using a real biomass as starting material for the preparation of sorbents for CO_2 capture applications. Sorption capacity of the obtained composite materials was tested on fixed-bed microreactor.

Kewwords: carbon dioxide capture, sorbent, rice husk, ferric oxide, fixed-bed microreactor.

1. Introduction

In this work testing composite material based on rice husk and ferric oxide/nanomagnetite. International scientists deserves greater emphasis to the problem of greenhouse gases emissions into the atmosphere. Specific importance was given to the development of CO_2 capture and storage strategies. To this aim, CO_2 capture and storage programm (CCS) is still considered the main strategy for achieving CO_2 emission reduction targets.

A lot of materials have been explored as CO_2 sorbent, including amine-impregnated solids, carbon-based and graphite/graphene-based materials, Layered double hydroxides (LDH)-based sorbents, zeolite-based materials, clay-based adsorbents, alkali metal carbonate-based adsorbents, Metal organic frameworks (MOF)-based sorbents, silica-based sorbents, polymer-based adsorbents, immobilized ionic liquid-based adsorbents, MgO-based sorbents, CaO-based sorbents, alkali zirconate-based sorbents, alkali silicate-based sorbents etc. [1-11].

Rice husk (RH) is an agricultural waste abundantly available in rice producing countries, obtained during the milling of paddy (22 wt.% of the weight of unmilled rice is received as husk). It presents a high ash content, which is 82 to 97% made by silica. RH being the outer shell of rice kernels protects the internal components from external attacks of insects and bacteria, but also RH need to get air and moisture for the growth of corn. Due to this peculiar function, rice in the process of natural evolution has created in its husk characteristics shapes with nanoporous layers. These properties let us applying RH in different field of science: in biomedicine and environmental applications, Li-ion battery anodes, as a fertilizer, as a mineral admixture in concrete, petroleum adsorption and etc. When RH is carbonized under controlled conditions its surface area and porosity increase making carbonized RH a good candidate for CCS approaches [12-16]. The carbonization of raw RH was performed in an auger furnace in the 500-800 °C temperature range for 3 h like in previous work experimental obtaining carbonized rice husk (cRH) [17].

2. Experimental part

Following the same approach with ferromagnetite (FM) reported in [17, 18] a set of five cRH/FM composites was produced by varying the amount of cRH from 0 to 100 wt.%. Starting form the procedure reported in [19] for the preparation of magnetite nanoparticles (nFM) in presence of a surfactant (TMAOH), a new approach was developed for the production of cRH/nFM composites by varying the amount of cRH from 0 to 100 wt.%.

More information about the composites, procedure of obtaining and other stuff provided on Fig. 1. By the way, we get 5 composites with different amount of magnetite and 5 composites with different amount of nanomagnetite (Fig. 2). Also obtained control samples of FM and nFM (without carbonized rice husk), two samples without ferric oxide cRH-NH_4OH and cRH-NaOH.

Elemental analysis. The differences in the compositions of the samples belonging to the two series can be explained by the effect of the synthetic conditions applied: the strong alkaline conditions generated by NaOH 5M allowed the SiO_2 dissolution on the contrary of NH_4OH (28%), thus in the series cRH/FM the content of inorganics is higher (Fig. 3).

Surface area (Fig. 4). The SiO_2 removal under strong basic conditions adopted during the synthesis of cRH/nFM samples allowed the production of sorbents with higher surface areas.

3. Results and discussion

Carbon dioxide sorption activity of cRH-NH_4OH and cRH-NaOH was assessed by tests in a fixed bed reactor with CO_2/N_2 gas mixture (15 Nl/h) at a fixed CO_2 concentration (3% vol), operating under atmospheric pressure. The CO_2 concentration in the inlet and outlet gas streams has been measured by online continuous ABB infrared gas analyzer. A laboratory scale fixed bed Pyrex microreactor (ID = 1 cm, length = 60 cm) operating under atmospheric pressure has been used for the preliminary evaluation of the CO_2 adsorption capacity of different samples. N_2 and CO_2 flowrates have been set by means of mass flow controllers (Bronkhorst), and subsequently mixed before entering the bed. The CO_2 concentration in the column effluent gas is continuously monitored as a function of time until the gas composition approaches the inlet gas composition value, until bed saturation is reached. The time taken by the gas mixture to flow from the fixed bed to the analyzer has been previously measured by flowing the gas mixture through the empty bed (about 50 s) [19, 20].
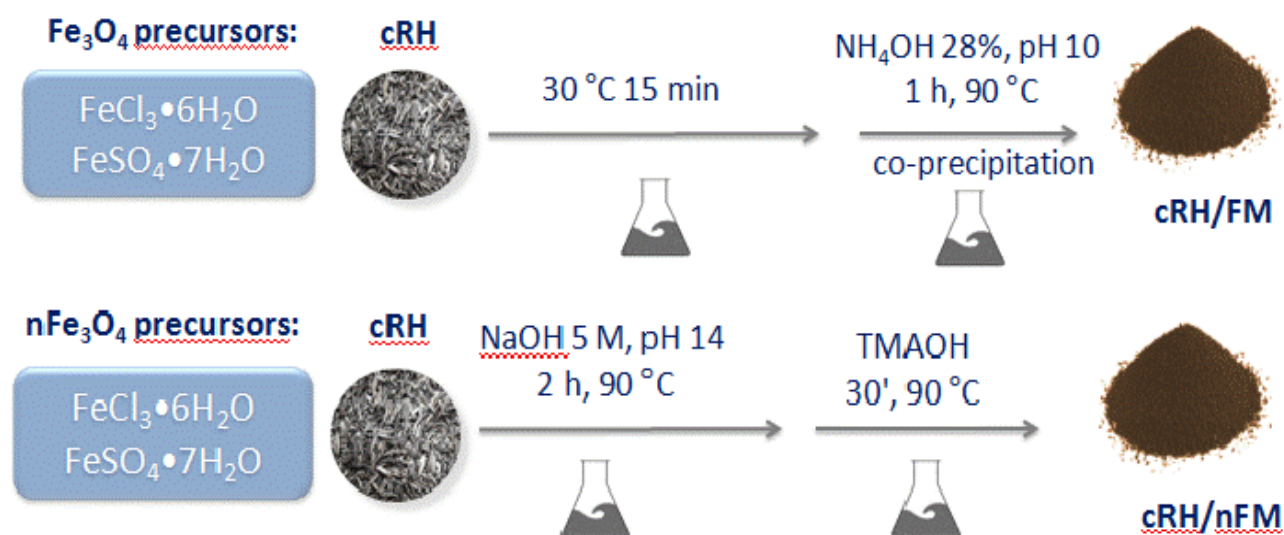

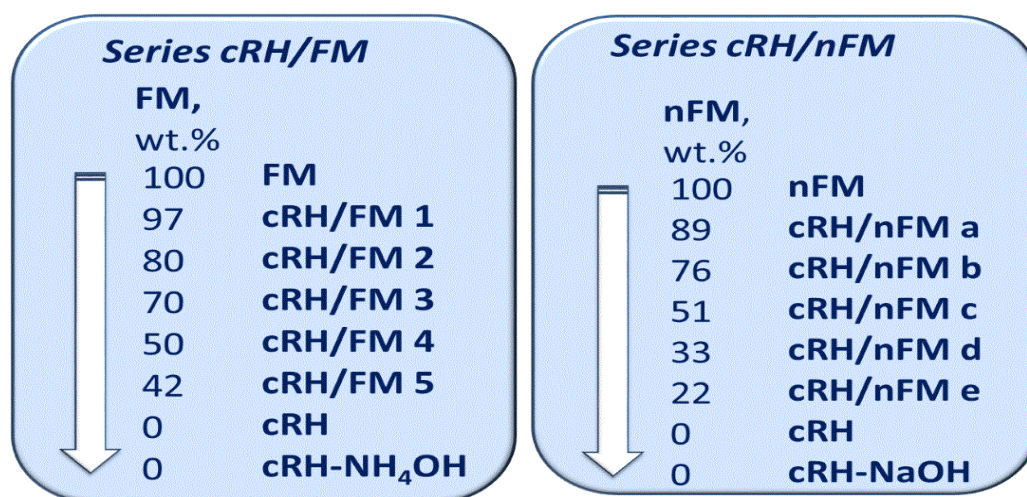Fig. 1. Schematic instructions for obtaining composites.

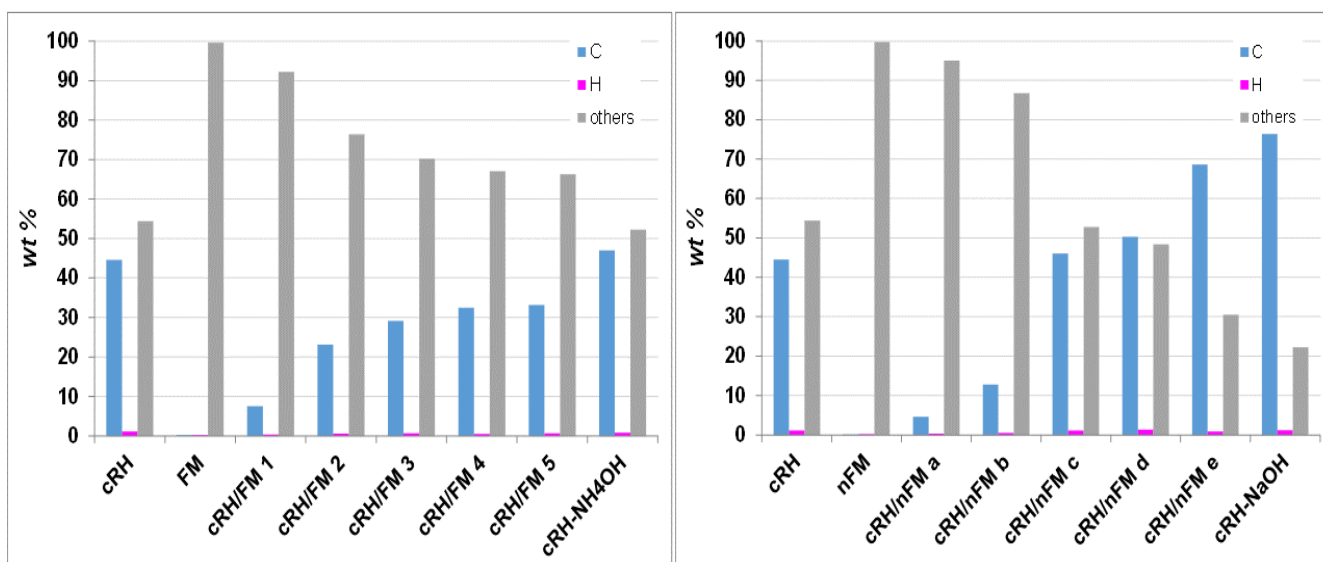Fig. 2. Two series of samples (simple and nano).
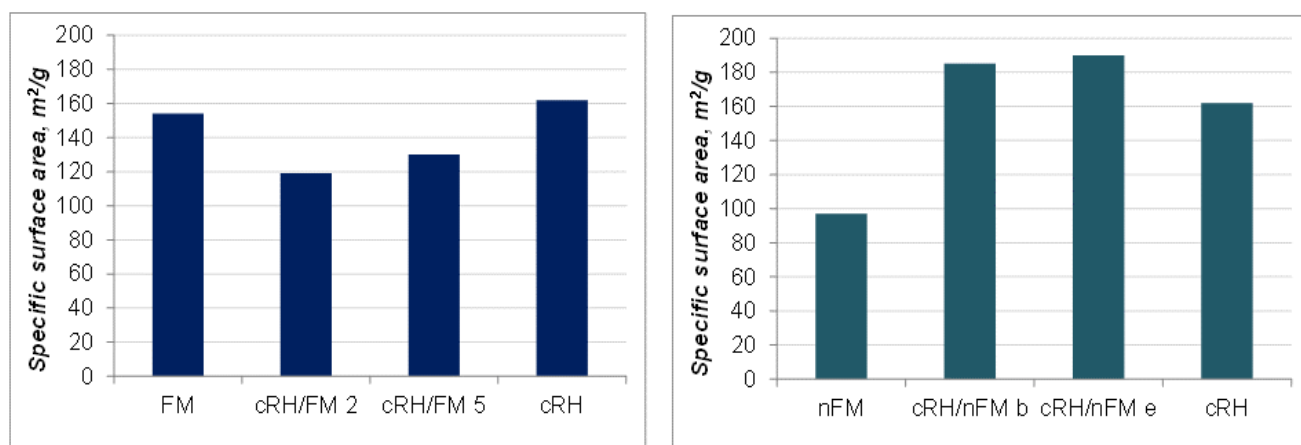
Fig. 3. Elemental analysis of samples.
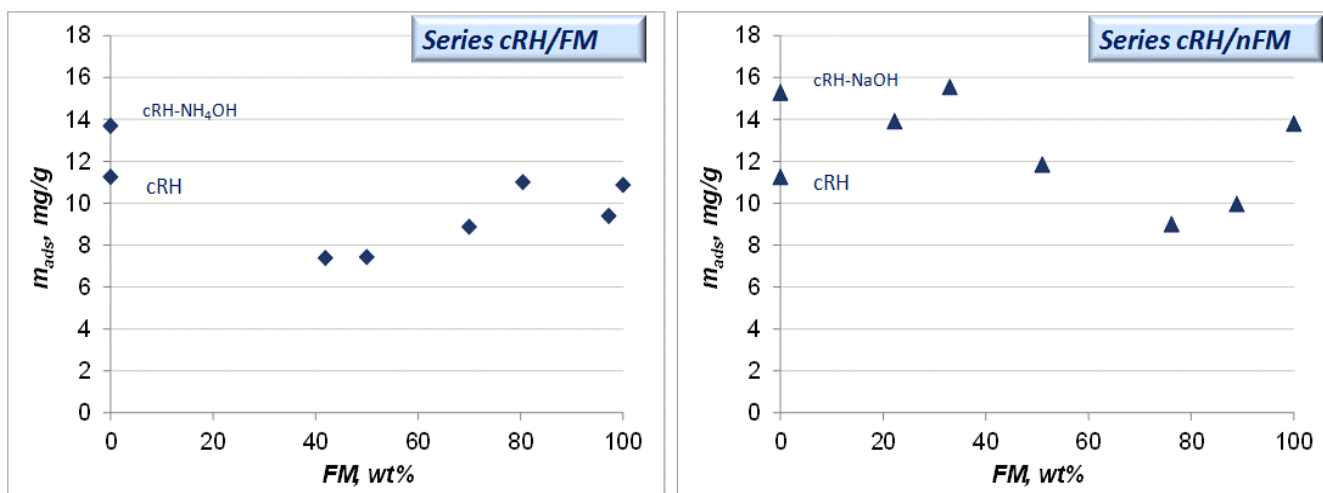

Fig. 4. Surface area data.

Fig. 5. Results of adsorption capacity of the samples from fixed bed microreactor.

These measurements were performed at Institute of Research Combustion IRC-CNR, Napoli, Italy (Fig. 5). Pure cRH in comparison with cRH-NaOH corresponded to an increment of 35% of CO_2 capture capacity (11,26 $mgCO_2/g$ versus 15,31 $mgCO_2/g$). First of all it is connected with removal of ashes of cRH.

Conclusions

These results indicated that the decoration of cRH with FM or nFM did not correspond to an advantageous increment of CO_2 capture capacities. But the removal of ashes corresponded to an increment of 35% of CO_2 capture capacity of cRH. Also the preparation of CO_2 sorbents like composite material based on biomass derived products and ferromagnetite must take into account the presence of ashes and their not adsorbing properties. These preliminary encouraging results find out the possibility to profitably and widely practice cRH as a low cost biomass-derived materials for CO_2 capture.

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Нанокомпозитный материал используемый в качестве сорбента по улавливания диоксида углерода

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Абстракт

В данной работе карбонизированная рисовая шелуха использовалась в качестве углеродной твердой матрицы для получения композиционных материалов, модифицированных частицами Fe_3O_4. Целью данного исследования является использование преимуществ и недостатков использования реальной биомассы в качестве исходного материала для приготовления сорбентов для приложений улавливающих CO_2. Сорбционную способность полученных композиционных материалов тестировали на микрореакторе с неподвижным слоем.

Ключевые слова: улавливание диоксида углерода, сорбент, рисовая шелуха, оксид железа, микрореатор неподвижного слоя.

Көміртек оксидын аулау үшін пайдаланған нанокомпозиттік материалдар

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Аңдатпа

Бұл жұмыста композитті материалды өндіру үшін карбонизацияланған күріш қабығы Fe_3O_4. бөлшектермен модификацияланған, қатты көміртекті матрица ретінде пайдаланған. Зерттеуі мақсаты пайдаланылатын көмірқышқыл газдарын шығаратын сорбенттерді дайындау үшін нақты материалдың биомассаларын артықшылықтары мен кемшіліктері пайдалануы. Алынған композициялық материалдардың сұранысқа ие сорбциялық мүмкіндігі микрореактормен қабжықталған.

Түйін сөздер: көміртек оксидын аулау сорбент, күріш қабығы, темір оксиді, статикалық төсек реакторы.