JOURNAL OF MULTIFUNCTIONAL MATERIALS & PHOTOSCIENCE
6(1), June 2015, pp. 11-19

A Review on New Trends and Capture Technologies for CO_2 Reduction through Various Semiconductor Photocatalysts

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Abstract: Thermal power plants fired by coal or the main source of CO_2 emission. During the combustion process various hazardous pollutant gases were produced which are fatal to environment. Among these produced environmental hazardous fuel CO_2 is the main contributor to global warming. Therefore it is very essential to fabricate and design new materials for CO_2 reduction purification technologies to keep the environment safe and secure. The paper demonstrates various CO_2 reduction/purification catalyst materials used in recent advanced technologies. A discussion on selection of suitable technologies barriers and different development stages has been discussed.

Keywords: CO_2 emission, Combustion, Various technologies, Catalyst technologies.

Introduction

Energy consumption form fossil fuels have a great importance because its concerns our daily needs. According to the British petroleum statically review of world energy 2014 [1], Global primary energy consumption increased by 2.3% in 2013 and 2012 (+1.8%). Growth in 2013 accelerated for oil, coal. But global growth remained below the 10-year average of 2.5%. According to the 2014 report the global consumption rate is rise more rapidly than production and also data suggests that growth in global CO_2 emissions from energy use also increased in 2013, so the shortage of fossil resource and increasing of CO_2 emission has already simultaneously stimulated sciences to research the utilization of CO_2 [2]. The consumption rates of energy increased during the period of 1961 to 2014. So global movement towards the generation of renewable energy is therefore under way to meet the increased energy needs, sunlight, winds, tides, waves, geothermal heat, biomass, and nuclear energy are the main renewable sources [3]. The consumption rate is higher than to the generation of renewable energy. The waste of energy is about 7-10TW while renewable sources like wind, hydroelectric and tide/ocean current provide almost 2.1TW, 1.5TW, and 2TW of energy respectively [4, 6]. Carbon dioxide plays an important role as

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well as a great contributor of the greenhouse effect. Which is the main cause of global warming [7,8]. According to the international energy agency (2012) [9], the aim of controlling climate warming to 2C is becoming more problematic and expensive with each year that passes. If the proper steps are not taken before 2017, all of the tolerable carbon dioxide emissions would be locked-in by the energy infrastructure existing in 2017. The plenty of CO_2 can be bifacial if it is properly utilized in solar fuel conversion [10], which is a recycling processes of CO_2 to control global warming, as well as the fuel crisis [11,12]. Furthermore many researcher try to develop efficient photocatalysts for the reduction of CO_2. The researcher have been developed TiO_2 [13-15], ZnO [13-16], CdS [17], Ta_2O_5 [18], $InTaO_4$ [19], used for the CO_2 reduction, but mostly investigated photocatalytic materials are TiO_2 (band-gap 3.2 eV) and ZnO. ZnO has suitable band-gap (3.37 eV), low cost, enviromental friendless and their electron mobility higher than TiO_2 [20-21].

Experimental Studies

Jun Cheng *et al.* [22] studied optimum conditions for CO_2 reduction to increase carbon atom and using a Pt-RGO||Pt-TNT photo electrochemical cell. The figure shows the rates of CO_2 reduction production generation and C atom conversion rate of the photoelectrocatalytic process C atoms initially increased and then decreased with increasing Pt-RGO reduction time. A maximum carbon atom conversion rate of 1180 nmol/(cm2 h) was obtained when Pt-RGO was reduced for 24 h.

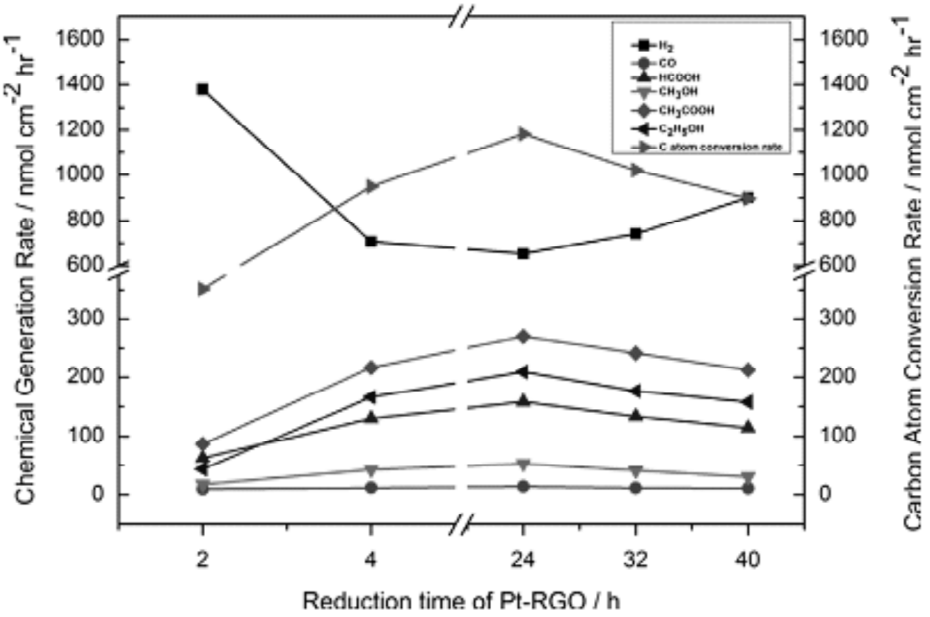

Figure 1: Carbon atom conversion rate and chemical generation rate in a photoelectrochemical cell with Pt-TiO_2 nanotube photoanode and Pt-modified reduced graphene oxide (Pt-RGO) cathode reduced for various times [22].

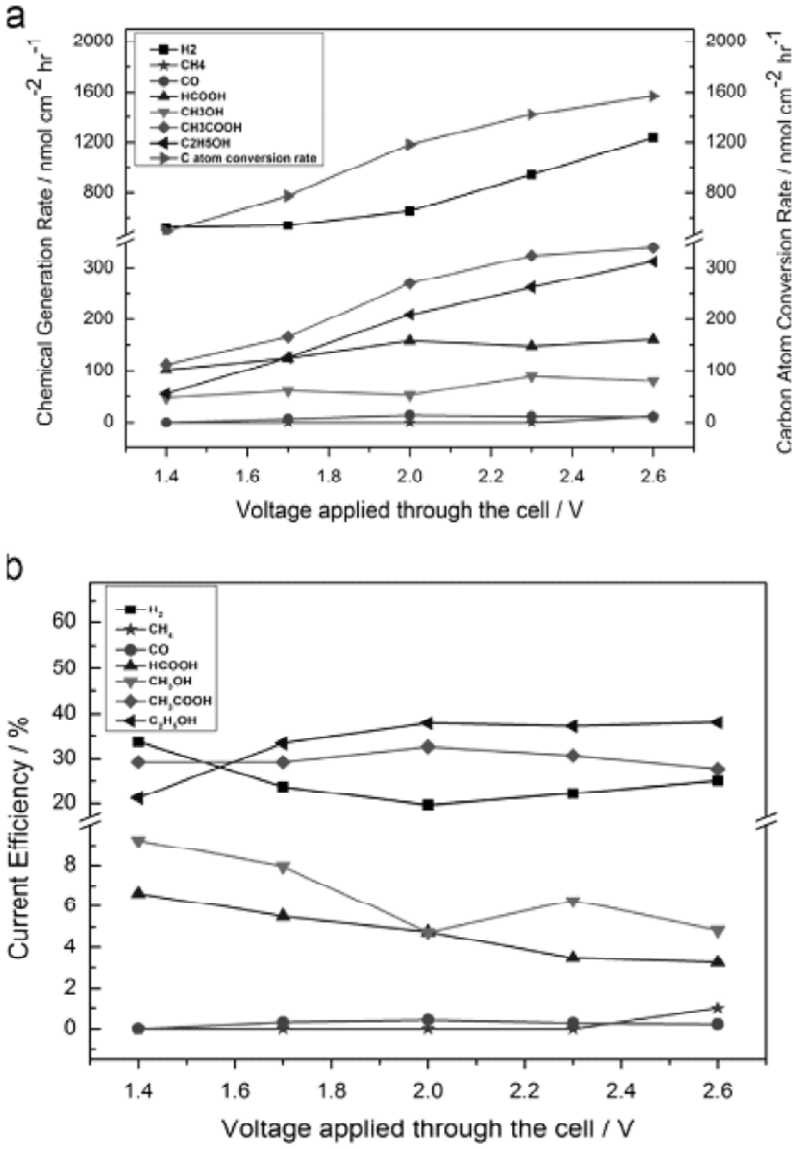

Figure 2: (a) shows the rates of CO_2 reduction product generation and C atom conversion as a function of the voltage applied through the PEC cell.methane was generated only when the potential applied was high, when the applied voltage was increased from 1.4 V to 2.6 V then the C atom conversion rate incrased form 490 nmol/(cm2 h) to 1560 nmol/(cm2 h).

Fig. 2. Carbon atom conversion rate and current efficiency in a photoelectrochemical cell with Pt-TiO_2 nanotubes photoanode and Pt-modified reduced grapheme oxide (Pt-RGO) cathode under various applied voltages: (a) C atom conversion rate and chemical generation rate, and (b) current efficiency. Note: Pt-RGO reduced for 24 h was used as cathode catalyst, and 110 PPI nickel form was used as catalyst support [22].

Nickel foam was selected as the catalyst support material in this study because of its large-area. Furthermore nickel foam was selected as the catalyst support material because of their unique properties (well-defined poresize, high conductivity and chemical stability) [23,24]. Fig. 3 shows that the rates of CO_2 reduction product generation and C atom conversion with different nickel foam pore sizes. Which shows that C atom conversion rate depends on nickel foam pore size. A maximum C atom conversion rate of 1500 nmol/(cm2 h) was obtained when nickel foam with an average pore size of 160 um was in used in the photocatalytic reaction.

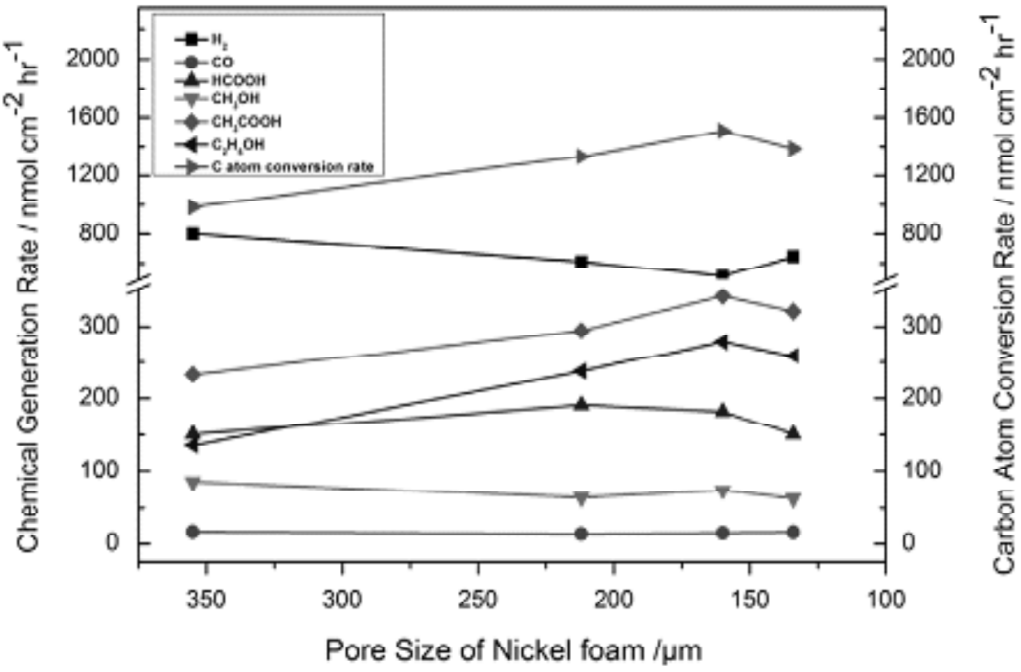

Figure 3: Carbon atom conversion rate and chemical generation rate in a photoelectrochemical cell with Pt-TiO_2 nanotube photoanode and Pt-modified reduced graphene oxide (Pt-RGO) on nickel foam with various pore sizes. Note: The voltage applied through the cell was 2 V. Pt-RGO reduced for 24 h was used as cathode catalyst, and the catholyte initial pH was 8.8 before CO_2 bubbling [22].

Qiuye *et al.* [25] developed a highly efficient Mgo/TiO_2 a unique one-dimensional (1D) nanotubes network (MgO/TNTs) films which exhibited excellent photoredution efficiency of CO_2 to methane compared with the bare TiO2 film. MgO has the strong adsorption ability of CO_2. MgO thin layer plays a important role in CO_2 methantion. For the improvement of photocatalytic activity Pt nanoparticles was loaded on MgO/TNTs films. The effect of the content of MgO and MgO/TiO_2 porous films on the photoreduction performance of CO_2 was shown Fig 4. The comparison tests consisted of a reaction under light without the catalysts and in dark with catalysts. A very trace amount of CH_4 and CO was delected.

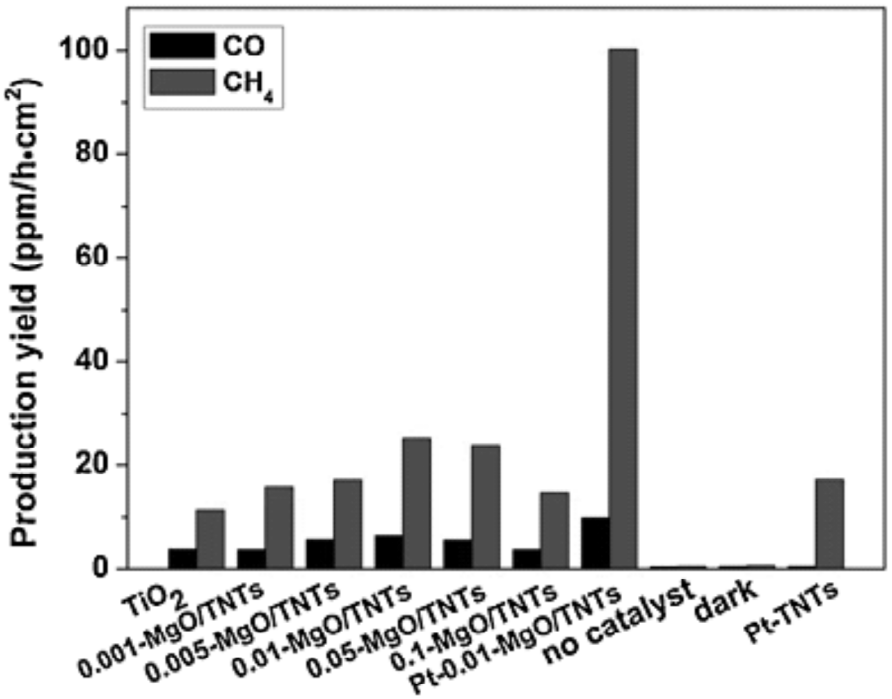

Figure 4: Photoreduction yield of CO_2 to methane and CO on the different films. From the figure 5 shown there is an optimum content of MgO for CO and CH_4 formation and their generation rate firstly increased and then decreased with the increasing of MgO [25].

Byeong Sub Kwak *et al.* [26] used pure TiO_2 and Ni incorporated TiO_2 with various molar fractions using solvothermal method. The figure 5 shown that the highest amount of methane was produced when light on and after 60 min irradiation the methane yield was Ni–TiO_2 (0.1 mol%) > Ni–TiO_2 (0.5 mol%) > TiO_2 > Ni–TiO_2 (1.0 mol%). The best catalyst was Ni–TiO_2 (0.1 mol%) with a maximum methane yield about 14 lmol/gcatal during 60 min. However, the yield of methane was gradually decreased in repeated time.

Ghader Mahmodi *et al.* [27] prepared photocatalysts (TiO2 and ZnO) on stainless steel mesh network was examined for photoreduction of CO2 gas and the result shown in figure 5 and 6. M Tahir *et al.* [28] used copper (Cu) and indium(In) co-doped TiO_2 nancatalysts for the photocatalytic CO_2 reduction with H_2.The catalysts prepared via modified sol-gel method. And figure 7 shown that both Cu and In co-doped to TiO_2 acted as efficient photocatalysts for CO_2 reduction. Further In co-doped TiO_2 catalyst for CO production was 3.23 time and higher than 3.5% In/TiO_2 and 113 time with un-doped TiO_2.

Lixin Zhang *et al.* [29] prepared ZnO-rGO used one-step hydrothermal method. Their experimental experimental results shown (Figure 8) that the Yield of CH3OH and ZnO-rGO was five times higher than pure ZnO.

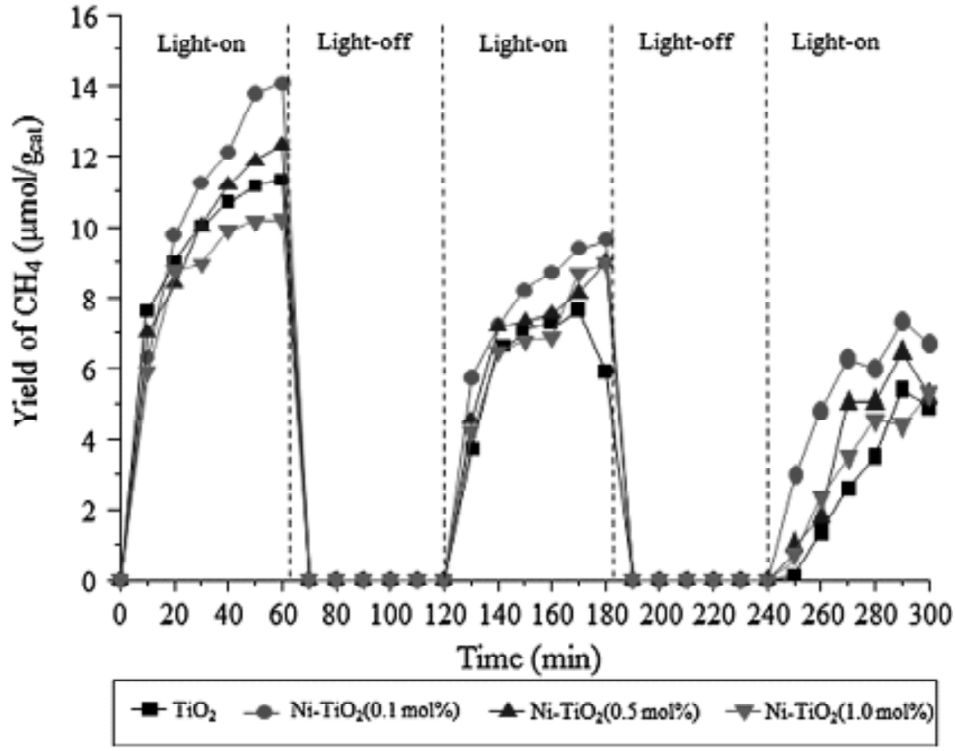

Figure 5: Photocatalytic CO_2 reduction with H_2O to CH_4 over TiO_2 and Ni–TiO_2. Ghader Mahmodi et. Al. [27] prepared photocatalysts (TiO_2 and ZnO) on stainless steel mesh network was examined for photoreduction of CO_2 gas .the Figure shown that TiO_2 coated mesh has best conversion percentage of CO_2 was reached in presence of water molecules [26]

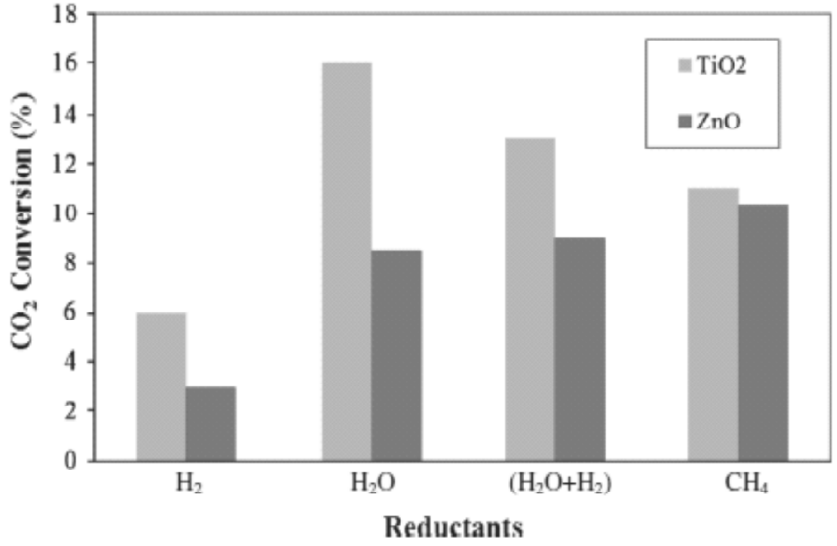

Figure 6: Conversion percentage of CO_2 in the presence of different reductants after 5 h [27].

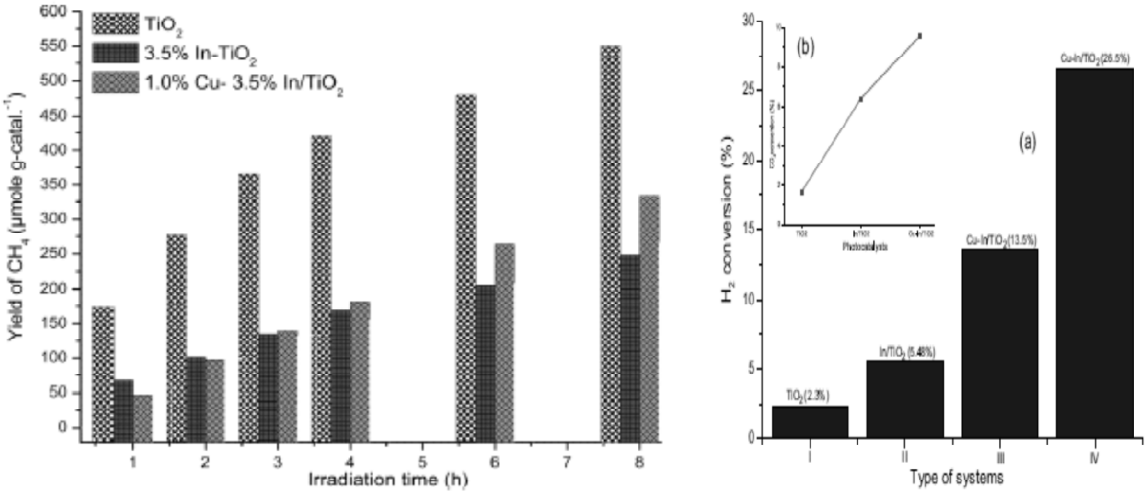

Figure 7: Photoreduction of CO_2 to CH_4 over un-doped and metal-doped TiO_2 monolithic catalysts at different irradiation times at 120æ%C and CO_2/H_2 ratio 1.5 [28].

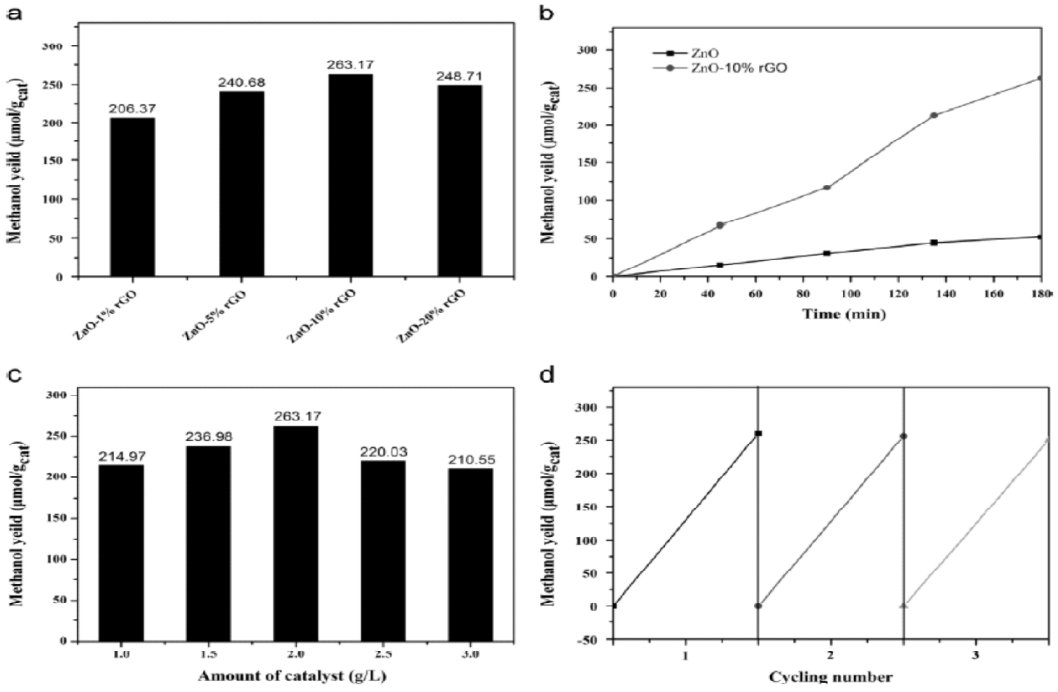

Figure 8: (a) methanol yield of photocatalytic reduction of CO_2 over ZnO-rGO composites with different amounts of rGO after 3 h reaction under UV–vis light irradiation, (b) the methanol generation over ZnO-10% rGO and pure ZnO under UV–vis light irradiation for 3h, (c) effect of amount of photocatalyst on the yield of methanol (d) repeated photocatalytic reduction experiments under UV–vis light irradiation for 3h [29].

E.S. Baeissa [30] prepared mesoporous graphene and tourmaline single and co-doped TiO_2 bye the sol-gel method and studied their physicochemical properties and their results shows that tourmaline percent plays an important role in determining the surface area and band gap of produced graphene-TiO_2. D. Chery *et al*. [31] studied reduction processes in molten carbonates. In presence of steam molten carbonates reduce CO_2 into CO or C. Two-steps reduction of CO_2 used to get an insight optimum condition. Which increase in the temperature will increase the electrochemical stability domain for CO but will alter the potentials of the system which is beneficial for the oxidative reaction.

Conclusion

In this review we discussed CO_2 emissions reduction technologies advancement and application. It is found that no single material or technology meets the requirements but instead the class of technologies needs to be developed and deployed to address the increasing energy use and CO_2 emission. Low selectivity and fewer availability of such materials to absorbed and reduce CO_2 is the main disadvantage in industrial application. All present technologies have their own advantages/disadvantages and restriction but their reduction/absorbance efficiency is the main difficulties. There is great need to understand the existing CO_2 reduction technologies to enhance the efficiency and fabricate cost effective catalyst materials for purification and reduction technologies.

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