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Vanadium Oxide based materials in advanced oxidacion processes (AOPs): state of the art and future perspectives

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Vanadium-based mixed oxide materials, bulk or supported, are well know as catalysts for total and partial oxidation reactions, and specially for those used fort he abatement of pollutants. Vanadium catalysts are effective for thermal, photo and electrochemical processes, being one oft he most promising catalysts for all these processes. In addition, the activity can be modulated by the use of a dopant or a support. A critical analysis of the literature fort he last decade as been performed, in order to discuss and analyze the possibilities and future perspectives on the use of these materials as environmental catalysis and specially for advanced oxidation processes.

Introduction: Vanadium Oxide-Based Materials in Envioromental Catalysis

Vanadium mixed oxide catalysts posses redox sites and are well known as oxidation catalysts. The chemical reactions that involve a change in the oxidation state of the products (oxidations and reductions) are of great importance in industrial chemistry and in environmental engineering, since most degradation reactions of pollutants involve oxidation or reduction. For catalyzing these reactions it is required that the catalytic material present redox sites, able to reduce and oxidize under reaction conditions, and catalyzing subsequently the oxidation/reduction of the starting molecule. A deep analysis of literature (Figure 1) regarding the use of VOx based catalysts show how the interest in the environmental applications is increasing and, in fact, in the last two years the majority of papers have focused on environmental processes. In order to have an idea about which are these processes, a bilbiomatric map has been perfomed with VOSviewer software (Figure 2), with all the articles with the key words “vanadium oxides catalysts” and “environmental”, those that appear with grey bars in Figure 1. Figure 2 clearly shows some clusters, one relative to selective catalytic reduction of nitrogen oxides (pink), other on selective and total oxidation processes (blue), and the rest are related with photocatalysis (green and purple) and electrocatalysts (yellow). These main clusters will be reviewer in order to understand the role of Vanadium catalysts in these important processes and to suggest future research directions in which we will focus to promote pollution abatement at low cost and with low-energy demanding processes.

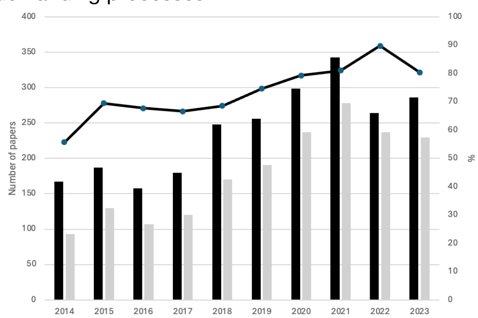

Figure 1. Number of articles publised by year druing the last 10 years with the key words „vanadium oxide catalysts“ (black bards) and, among thse, those that have „environmental“ (grey bars). The line indicate the % that grey bars represent with respect black ones. Note: words in title, abstract of keywords searching at Scopus.

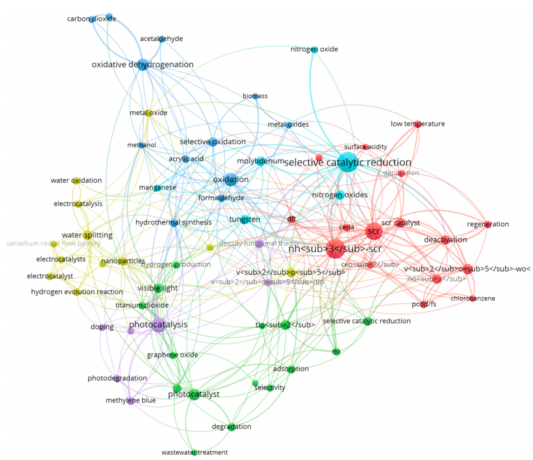

Figure 2. Bibliometric map of keywords from articles indexed by Scopus from 1014 to 2023 (1793 papers) with the key words „vanadium oxide catalysts“ and „environmental“ in title, abstract of keywords.

Total Oxidation Process

Vanadium catalysts are useful fort the rapid degradtation of organic molecules since they are able to oxidize them since they are able to be with oxidation states V, IV, and III, and to interconvert with relative ease, which makes them effective oxidation catalysts. The oxidation activity can be modulated by the use of a dopant or a support [1].V-W-O supported catalysts are reported as efficient for the total oxidation of most of organic pollutants, due to a synergy between V and W, that increases the number of Brønsted acid sites, that favor the adsorption oft he VOC molecule [1]. Vanadium based catalysts are also useful as promoters Fenton oxidations, since their redox sites are able to decompose H2O2 to hydroxyl and superoxide radicals [2].

Photocatalysis and electorchemical processes

Electrochemical advanced oxidation process, as well as photocatalytic ones, are receiving great attention during the last decade since they are useful for water treatment technologies, since they are able to mineraliza pharmaceuticals and other dangerous organic emerging pollutants. In addition, they have proved tob e useful for the production of H_2 from water or methane/methanol from CO_2, which are also important processes related with sustainability.

Bismuth Vanadate $BiVO_4$, as well as V-doped TiO_2, are promising photocatalysts, since they are semiconductor materials with low toxicity, low production cost, resistance to corrosion, In addition, nanostructured VO_2 particles are also a semiconductor material that can have a band gap of ≈2.7 eV and that shows a promising photocatalytic activity for hydrogen production [3,4]. The reusability tests for these materials [5] also proved that they present a high stability. V- based catalysts are also useful fort he photocatalytic ozonation. It has been shown [6] that $BiVO_4$ is an attractive catalysts for such process that combines photocatalysis and ozonation. Thus, these are just a few examples that show the possibilities of vanadium compounds in both photocatalysis and electrochemical process that are opening new perspectives in the design of advanced oxidation processes for removal of pollutants.

Electrochemical advanced oxidation processes are being also developed fort he degradation of a wide range of organic pollutants mainly due to the electrochemical generation of hydroxyl radicals on the anode surface. Several electrode materials are being investigated for these processes, such as those based on PbO2, SnO2, TiO2 or IrO2, and it has been reported that when those materials are doped with V species, or by the coating oft he electrodes with Vanadium, the electorde performance and stability improves [7]

Conclusions

Present perspective review paper underlines the possibilities of vanadium compounds in redox catalysis for environmental applications, due tot he possibility of vanadium oxides to have different oxidation states during reaction. The catalytic properties can be modulated by the use of a dopant and/or a support, opening a wide range of applications in thermal-, photo- and electro– catalytic processes.

Acknowledgments

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