IOCN 2025 Conference

The 5th International Online Conference on Nanomaterials

22–24 September 2025 | Online

MDPI

Effect of doping on the catalytic activity of materials based on TiO_2 for VOCs degradation

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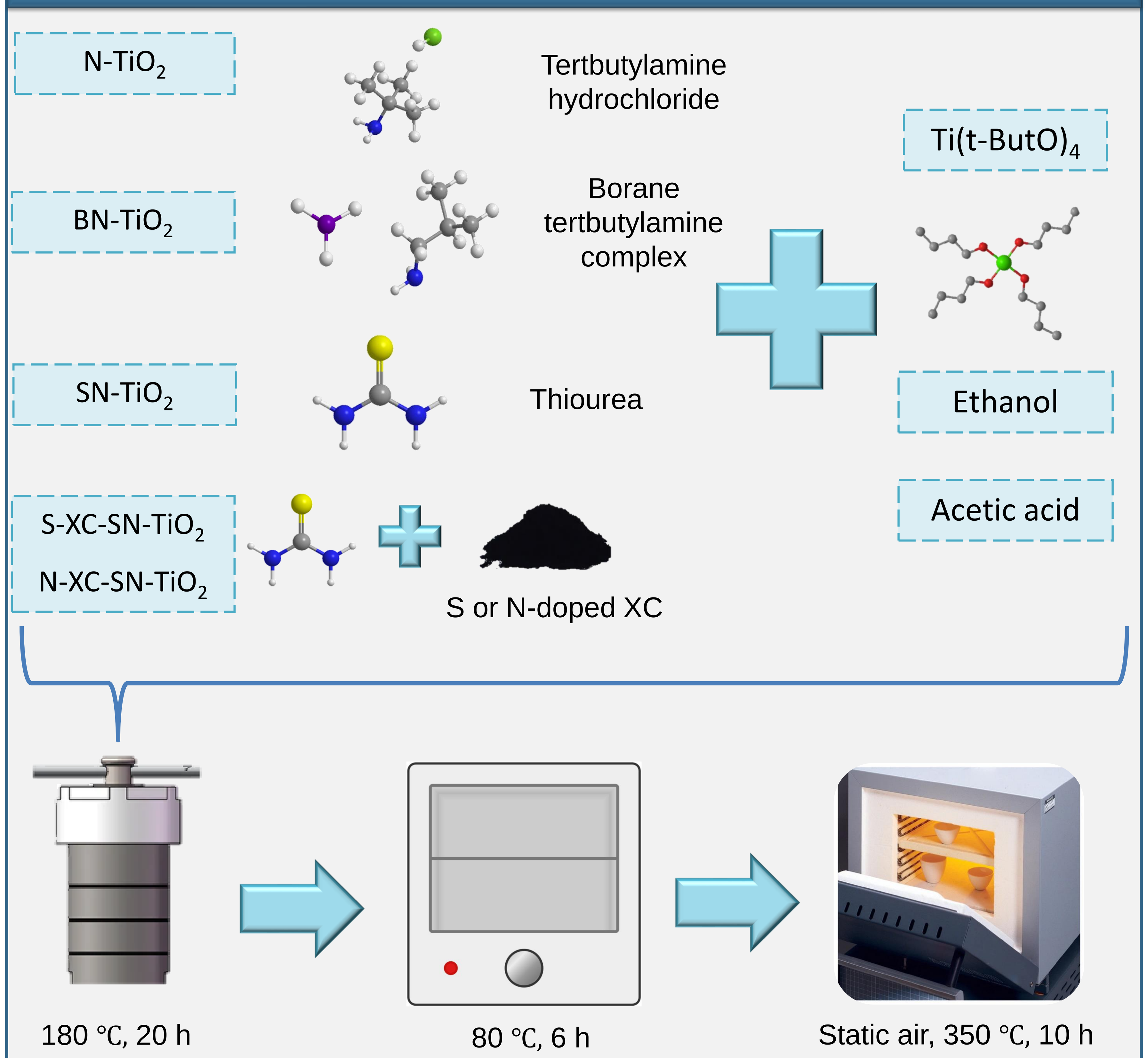
INTRODUCTION & AIM

Volatile organic compounds (VOCs) are organic contaminants with boiling points below 250 ºC at normal temperature and pressure. They are regarded as one of the primary contributors to air pollution, with effects ranging from ozone layer reduction or climate change to different human diseases. For these reasons, it is important to reduce their emissions as well as diminish indoor exposure. Usually, different separation methods such as absorption, condensation or membrane separation, along with thermal oxidation, have been used for their removal. However, they are not exempt of limitations regarding their low removal efficiency, high cost or generation of toxic by-products due to incomplete combustions. Therefore, new approaches are required such as adsorption and photocatalytic oxidation. Regarding photocatalytic process, TiO_2 is one of the most widely used semiconductors due to its low cost and toxicity and high stability. However, the wide bandgap of its most photoactive phase (3.2 eV, anatase) reduces its application under visible or solar radiation. Several alternatives have been proposed to overcome this problem, such as doping titania with heteroatoms or the synthesis of composites with carbon materials, to enhance its activity through the synergetic effect between both phases.

In this study, a series of titania (TiO_2) doped with 2 wt.% of different heteroatoms (N and B, N and S, and only N) were synthesized by a hydrothermal route. The physico-chemical properties of the materials were analyzed by different techniques, and their photocatalytic performance was assessed for the removal of ethylene and toluene, as target VOCs, under visible radiation and dynamic conditions. The effect of humidity (30% RH) in the feed stream on the activity of the samples was also studied. A selected doped-titania was also combined with a sulfur or nitrogen-doped carbon xerogel (XC) to study the co-doping effect in titania and carbon phases simultaneously, under the same experimental conditions.

METHOD



RESULTS & DISCUSSION

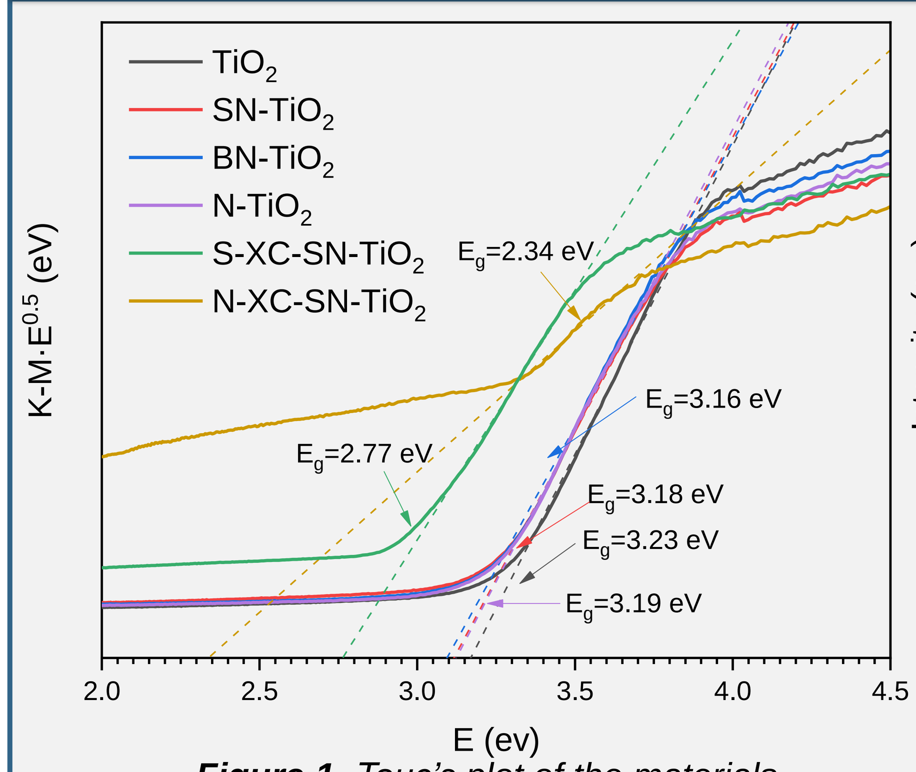


Figure 1. *Tauc's plot of the materials.*

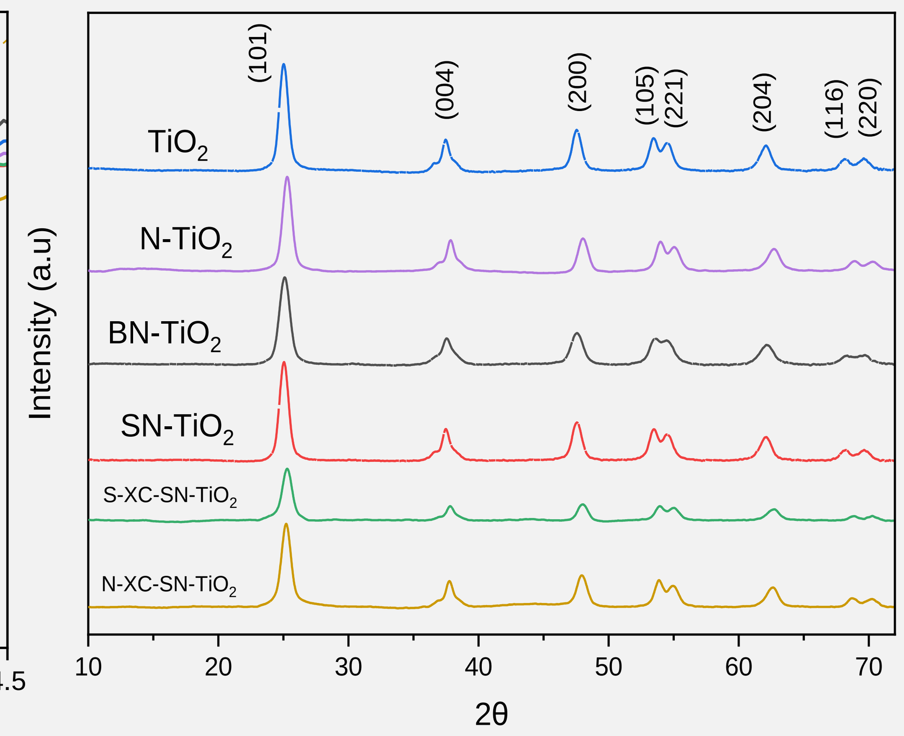


Figure 2. *XRD patterns of the samples.*

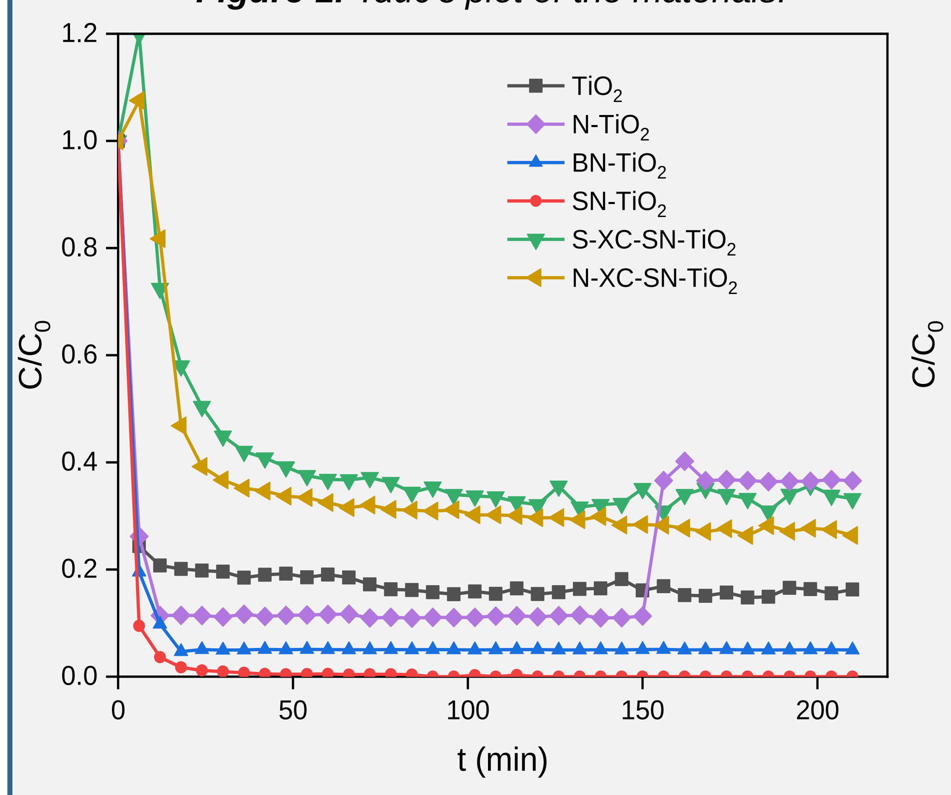


Figure 3. *Ethylene degradation in dry conditions and visible radiation.*

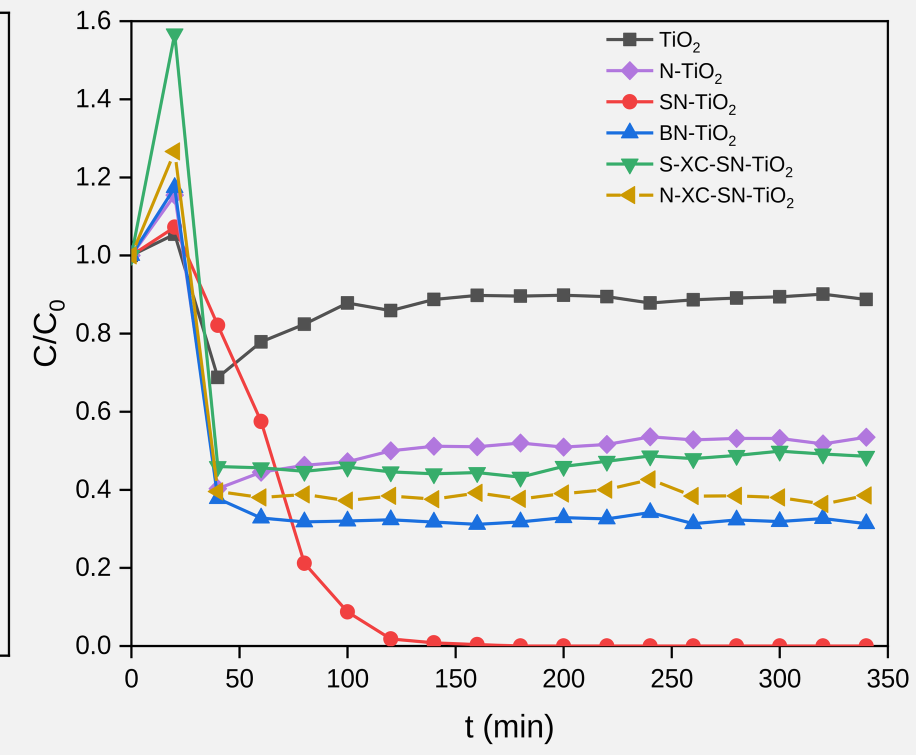


Figure 5. *Toluene degradation in dry conditions and visible radiation.*

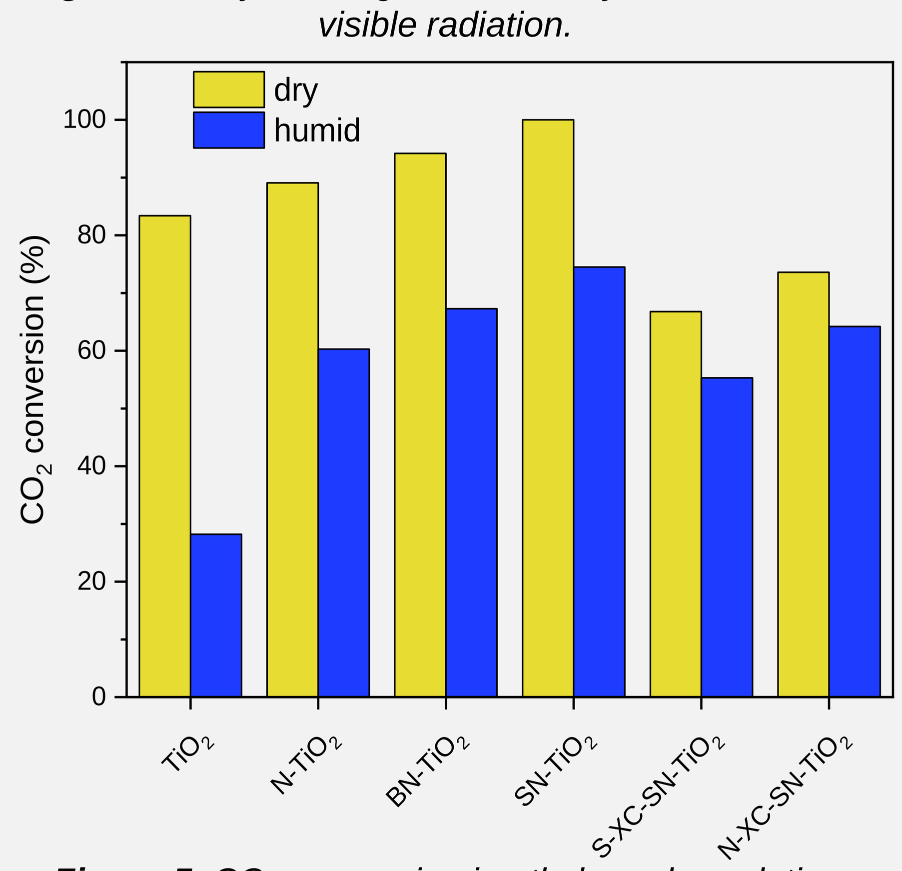


Figure 5. *CO_2 conversion in ethylene degradation, in dry and humid conditions (Vis radiation).*

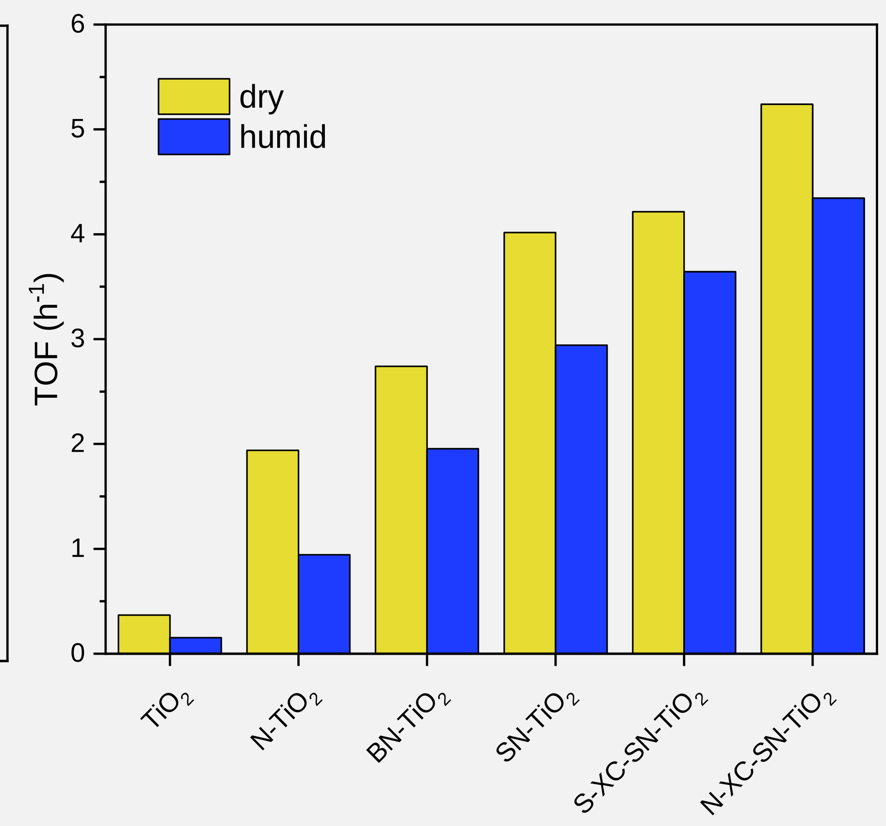


Figura 6. *TOF values of toluene degradation, in dry and humid conditions (Vis radiation).*

- XRD analysis confirms the presence of TiO_2 in anatase form for all materials. Crystallite sizes diminished with doping and specially in the composites The addition of the carbon xerogel in the materials was able to diminish bandgap values in the composites to 2.8 eV for the S-doped and 2.3 eV for the N one **(Figures 1 and 2)**.
- All materials were active in the degradation of both VOCs under dry conditions and visible radiation, although N-TiO_2 and TiO_2 seem to show some deactivation. Co-doped samples (SN and BN) improved the activity and avoided deactivation **(Figures 3 and 4)**. However, the performance of all samples diminishes with the presence of humidity **(Figure 5)**. To improve the TiO_2 performance, various SN-TiO_2-carbon composites were tested, achieving significant benefits in terms of TOF values and an enhancement of activity under humid conditions, due to the synergy between phases, especially with the higher electronegativity of N-XC-SN-TiO_2 **(Figures 3, 4, 5 and 6)**.

CONCLUSION

With our approach, we were able to combine different strategies to enhance TiO_2 activity: co-doping and supporting TiO_2 nanoparticles on carbon materials, achieving the introduction of a higher doping percentage as well as a successful decrease in bandgap energy in the composites. Overall, the N- doped composite with SN-TiO_2 emerged as the most effective photocatalyst, due to its lower bandgap and higher electronegativity, highlighting the synergistic effect of co-doping and carbon support integration.

FUTURE WORK / REFERENCES

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- G. Zhang, Y.C. Zhang, M. Nadagouda, C. Han, K. O'Shea, S.M. El-Sheikh, A.A. Ismail, D.D. Dionysiou, Visible light-sensitized S, N and C co-doped polymorphic TiO_2 for photocatalytic destruction of microcystin-LR, Applied Catalysis B: Environmental 144 (2014) 614-621.

Acknowledgements: This work was financially supported by the project ref. PID2021-126579OB-C31 by MCIN/AEI/10.13039/501100011033 and FEDER "Una manera de hacer Europa" and by Junta de Andalucía - Conserjería de Universidad, Investigación e Innovación - Project (P21_00208). LTPP (FPU22/01255) and SMT (RYC-2019-026634-I) thank MCIN/AEI/10.13039/501100011033 and FSE "El FSE invierte en tu futuro" for their FPU and Ramón y Cajal contracts, respectively.

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