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Synthesis and Characterization of Materials Based on Metal Oxides Combined with MXenes: Photocatalytic Applications

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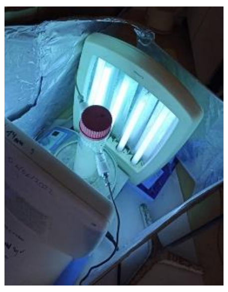
Introduction & Objective

When considering the possibilities of scaling up the photocatalytic production of hydrogen, TiO_2 presents a significant disadvantage: its absorption capacity is mainly limited to the near-ultraviolet region (UVA). Since ultraviolet radiation constitutes only about 5% of the electromagnetic solar spectrum, it is necessary to modify its structure to enhance absorption in the visible region and thus better harness the available solar spectrum. This objective can be achieved by incorporating metals or semiconductors [1] such as perovskites and MXenes.
This study examines the effect of these materials on TiO_2 for hydrogen production.

Experimental

Hydrogen production
50 mL of methanol measured and filled up to 200 mL in a volumetric flask. 0.2 g sample introduced into a photoreactor with methanol. Reactor connected to gas chromatograph (TCD) after purging with nitrogen. Flow reduced and lamps (Philips HB 175) turned on. Hydrogen amount measured through calibration with pure hydrogen and nitrogen flows. Shimadzu GC-2010 chromatograph used with Mol Sieve 5 Plot column.



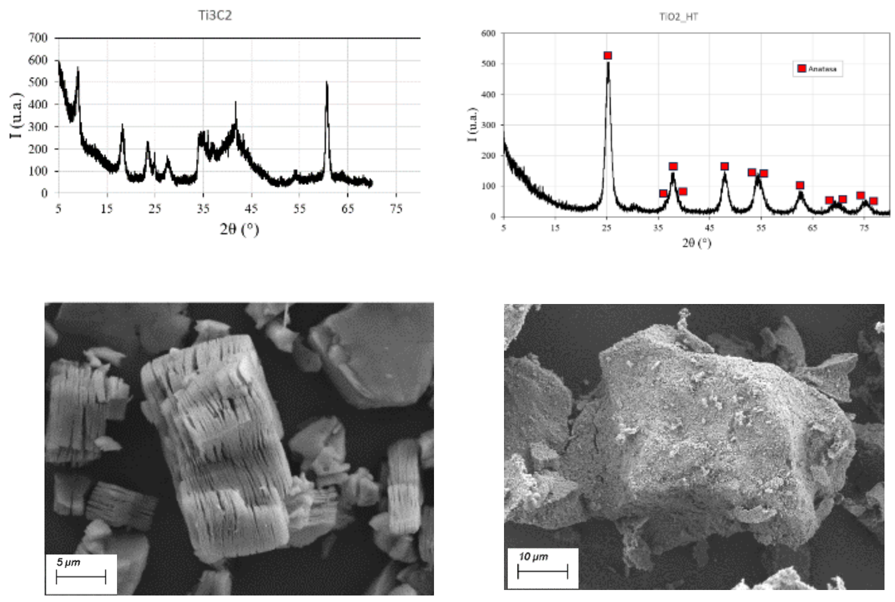
Photoreactor illuminated by lamps.

Mxene synthesis
2.5 grams of Ti3AlC2 are added to a 48% HF (hydrofluoric acid) solution in an exothermic reaction with agitation. After adding all the solid, it is stirred for 8 hours at 50ºC to remove the present aluminum. Subsequently, it is centrifuged to separate the solid from the liquid, and it is repeatedly washed with water until reaching a neutral pH. Finally, it is dried in an oven at 60ºC for 12 hours.

Centrifugation suspension to obtain MXene.

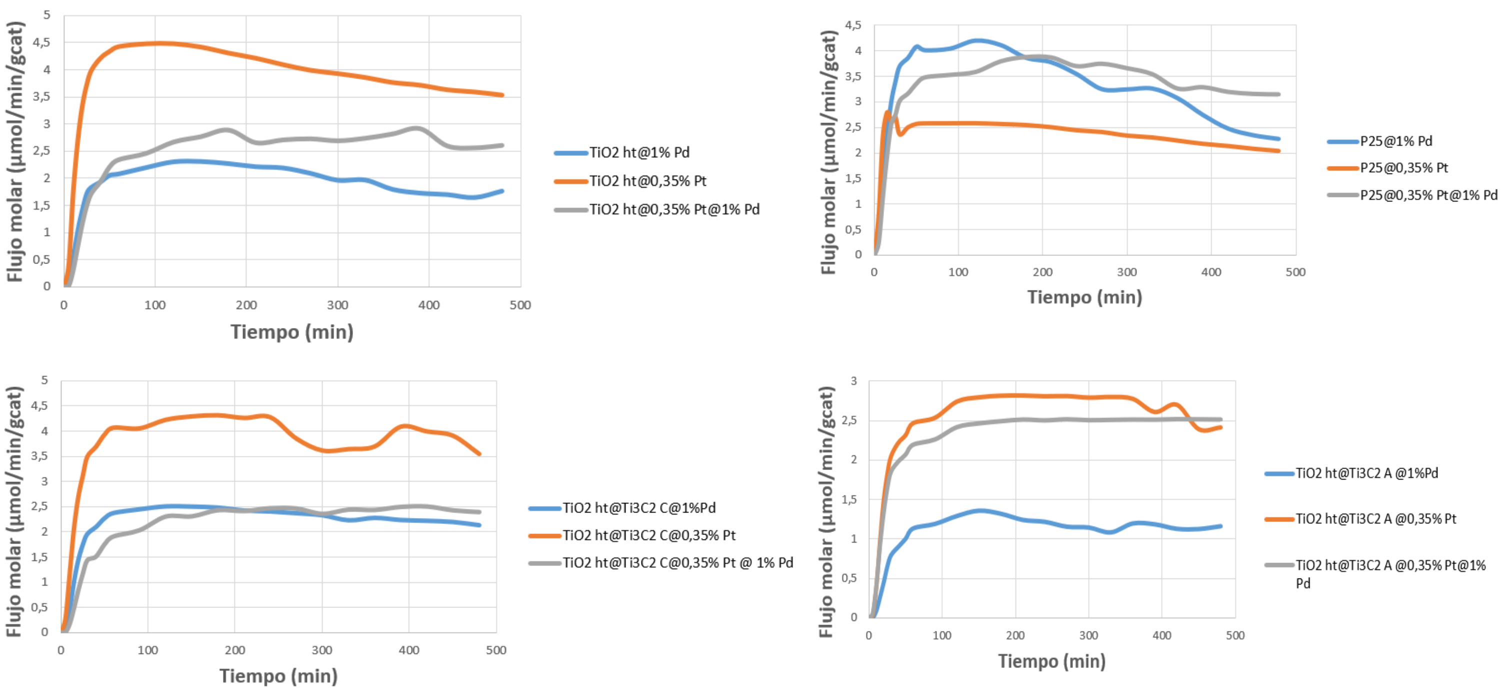
In addition, metal depositions were performed on the samples. Palladium deposition was carried out through chemical reduction, and platinum deposition was achieved through photodeposition.

Characterization



XRD graphs and SEM photographs of Mxene (left) and TiO2 ht (right).

Results



Hydrogen production over time graphs for the samples.

From the graphs, it can be observed that hydrogen production is more favored by platinum deposition in the samples (except for the P25 sample group). On the other hand, Mxenes do not seem to be as influential in increasing production. In fact, generally, the samples that only have metal depositions show better performance than those that incorporate Mxene. However, MXenes have been shown to be successful in reducing the bandgap of the samples and increasing their absorption range in the electromagnetic spectrum.

Conclusions

In conclusion, platinum deposition in the samples appears to be the most efficient in terms of hydrogen production.
On the other hand, Mxene seems to have succeeded in extending the absorption range of the samples in the electromagnetic spectrum. As for samples that have shown good hydrogen production and a significant reduction in bandgap, we can highlight the sample: P25@0.35% Pt@1%

References: 1. K. Villa Gómez, «Estudio de la producción de hidrógeno mediante fotocatálisis heterogénea,» Barcelona, 2013.

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