Titania Quantum Dots Assemblies (Pt/TiO_2–QDs, Pd/TiO_2–QDs) by Flame Spray Pyrolysis for Superior Artificial Photosynthesis

ID 1621

16ο ΠΑΝΕΛΛΗΝΙΟ ΣΥΜΠΟΣΙΟ ΚΑΤΑΛΥΣΗΣ 20-22 ΟΚΤΩΒΡΙΟΥ 2022 ΧΑΝΙΑ

C. Dimitriou, C. Moularas, M. Solakidou, P. Stathi, Y. Deligiannakis*

Laboratory of Physical Chemistry of Materials & Environment, Department of Physics, University of Ioannina (UOI)

Introduction

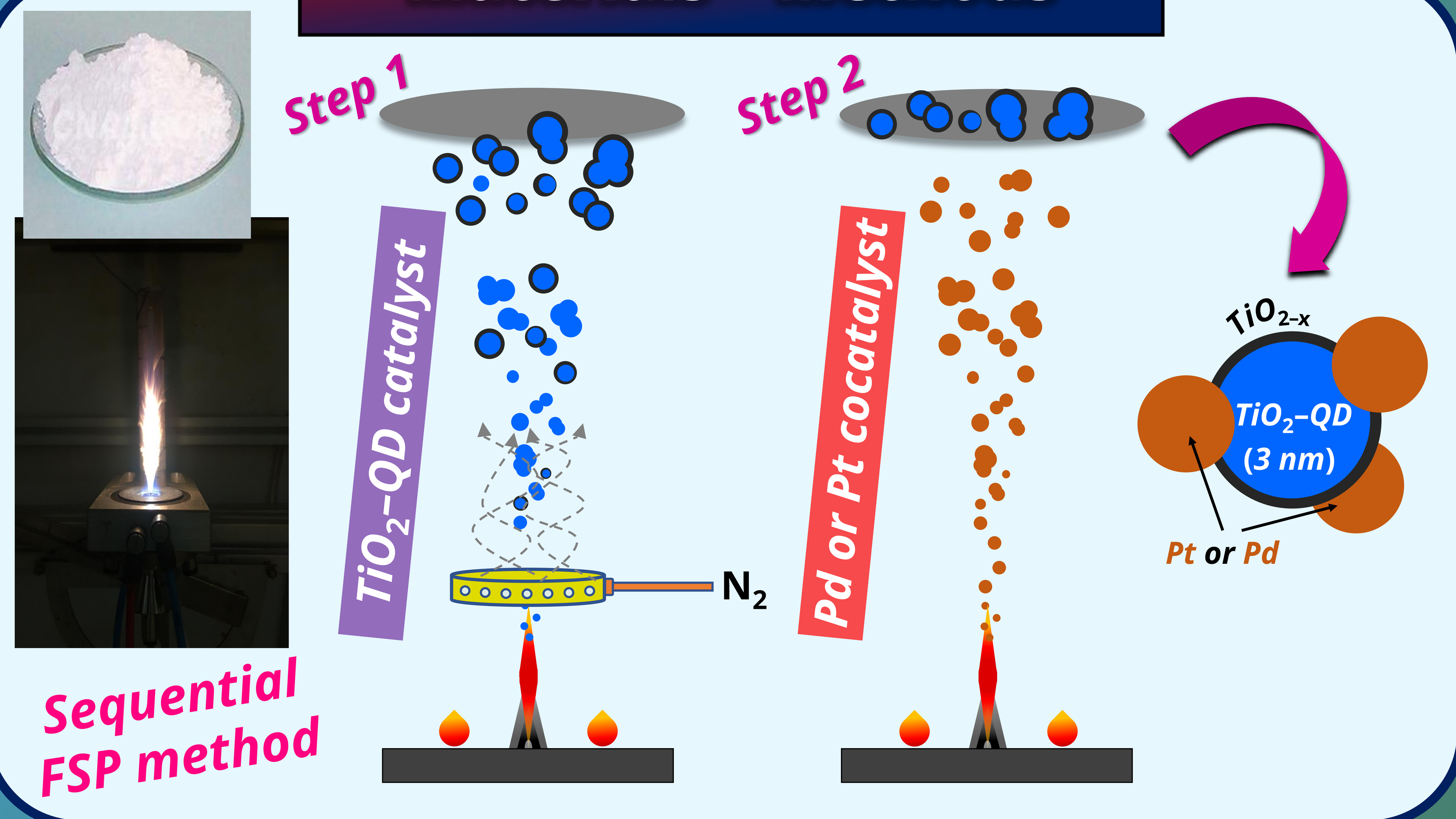
The extraordinary optical and electrical characteristics of quantum dots (QDs), such as their high quantum efficiency, narrow size-dependent absorption, and luminescence windows, have attracted a great deal of attention. Metal oxide quantum dots have a wide range of applications, including photocatalysis (TiO_2), ultraviolet (UV) protection coatings (ZnO), high-temperature superconductors (CuO) and gas sensing (SnO_2). The equation that governs the relationship between the crystal size in terms of radius R and bandgap energy E^*

$$E^* = E_g + \frac{\hbar^2\pi^2}{2R^2}\left(\frac{1}{m_e}+\frac{1}{m_h}\right) - \frac{1.8e^2}{\varepsilon R} - 0.248E_{Ryd}$$

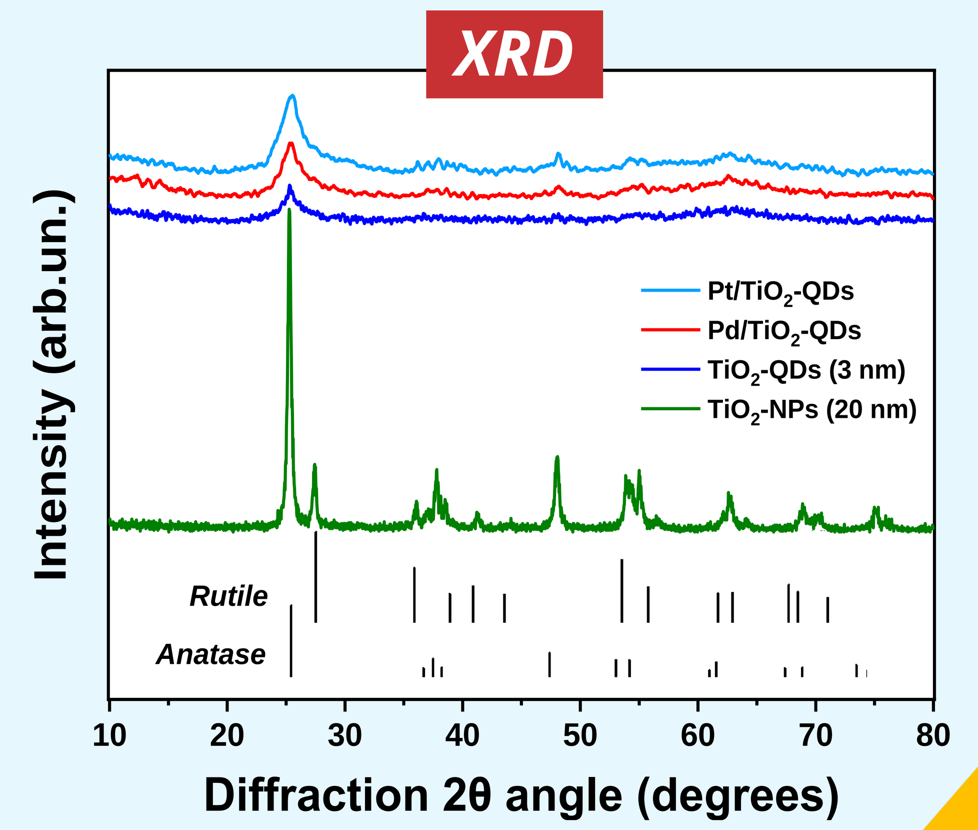
where E_g is the bulk bandgap energy (at $R \to \infty$), m_e and m_h are the electron and hole effective masses, ε is the dielectric constant of the material and E_{Ryd} the Rydberg energy term. The above equation illustrates that the quantized effect is most significant at sizes below the exciton Bohr diameter but still occurs at bigger sizes.

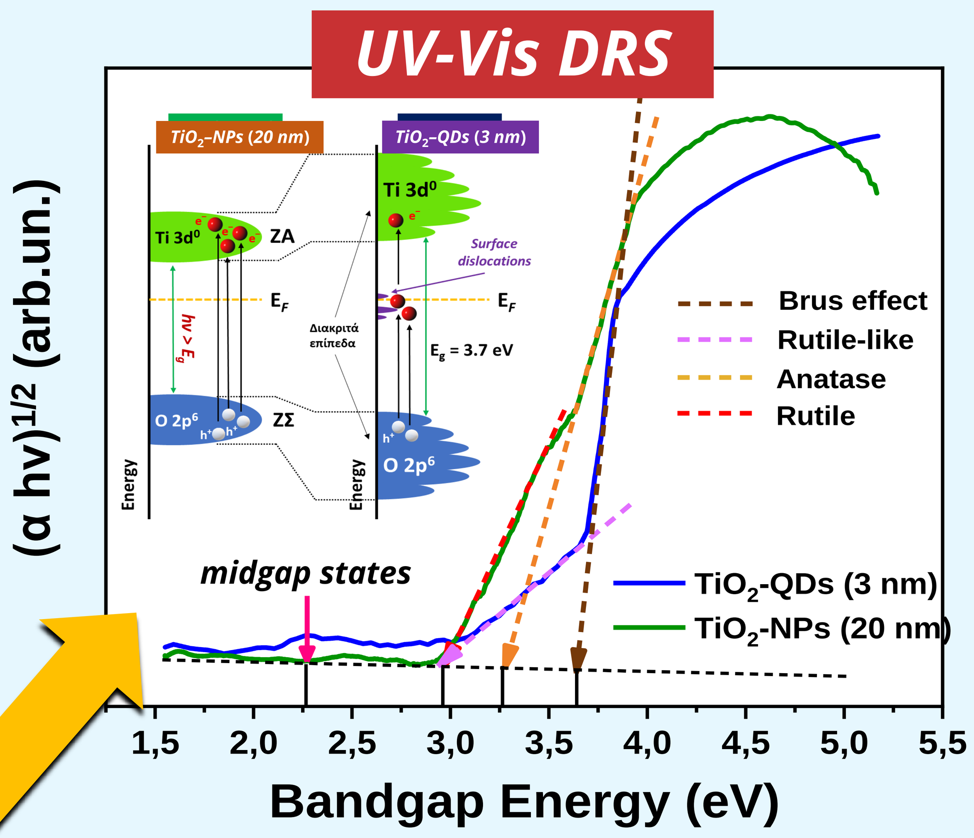
In the present work, TiO_2 QDs were synthesized and decorated with either 1% Pt or 1% Pd nanoparticles utilizing the innovative sequential Flame Spray Pyrolysis (FSP) method. Finally, these nanoparticles were studied for artificial photosynthesis, i.e. the H_2 production by H_2O splitting and the HCOOH formation by CO_2 reduction.

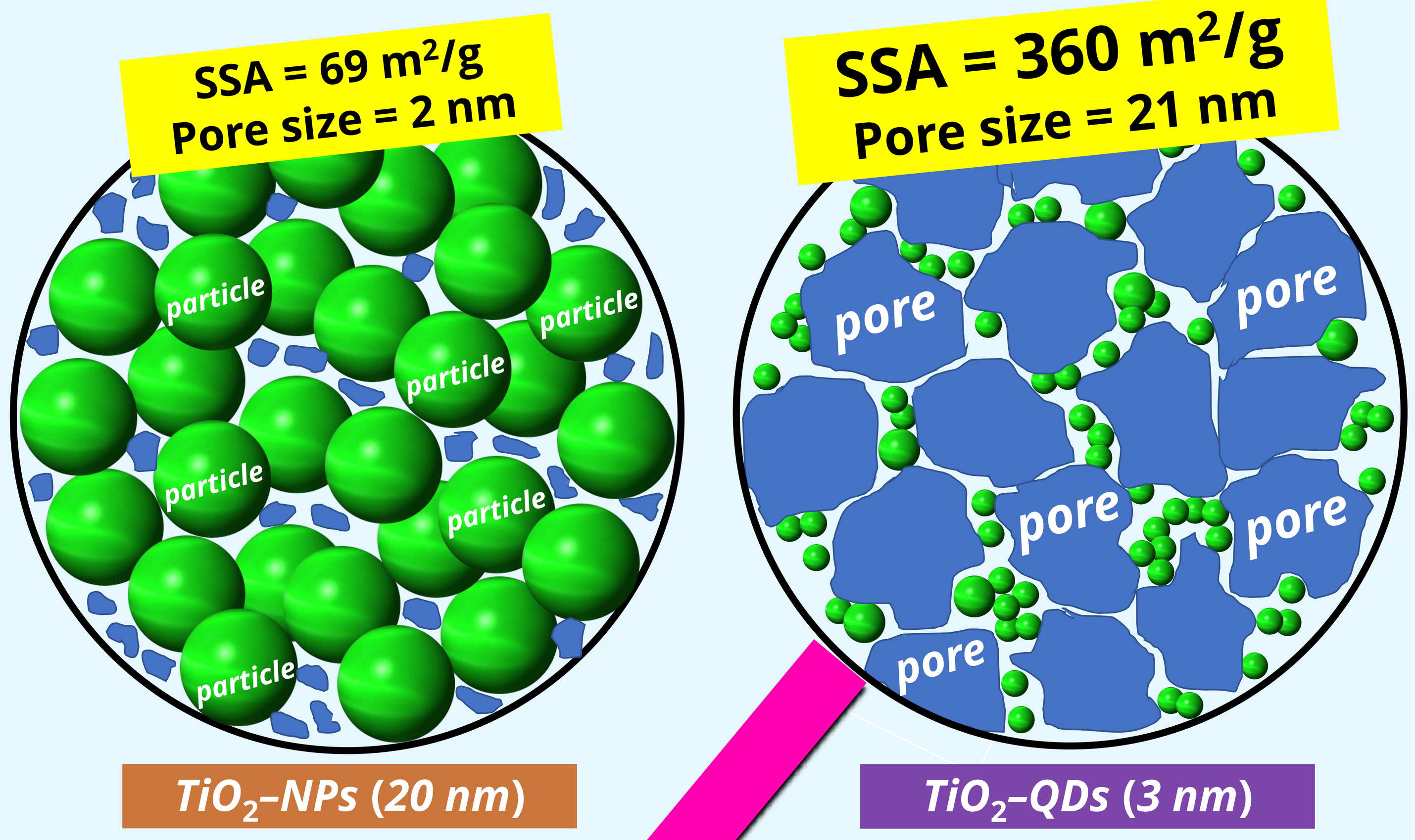
Materials – Methods

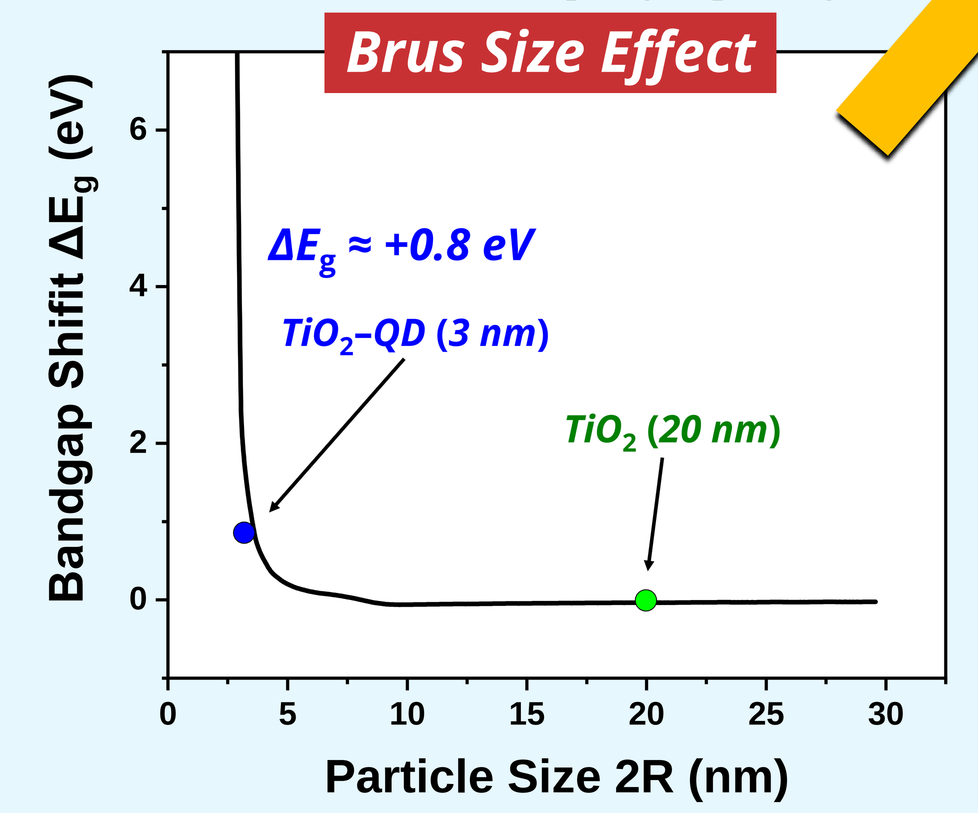


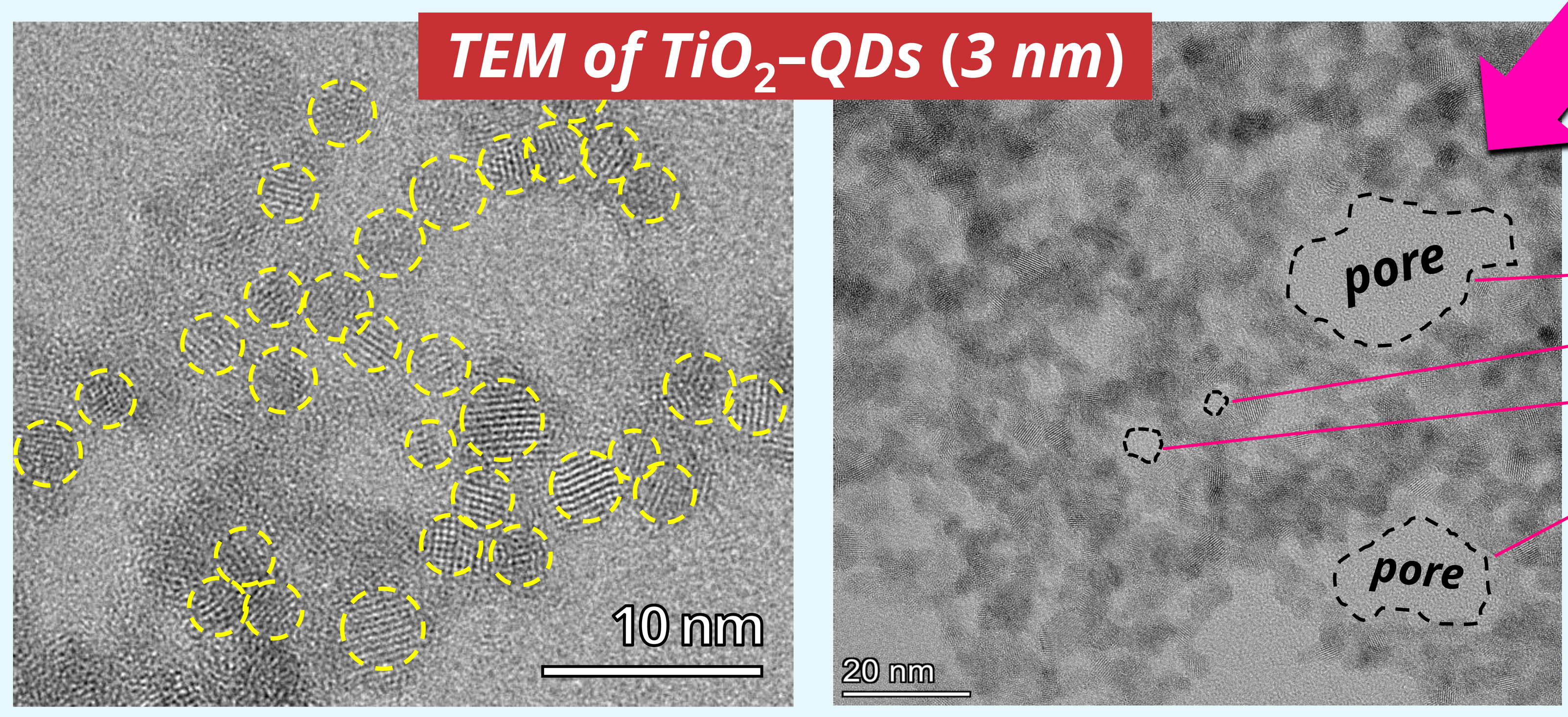
Results – Discussion

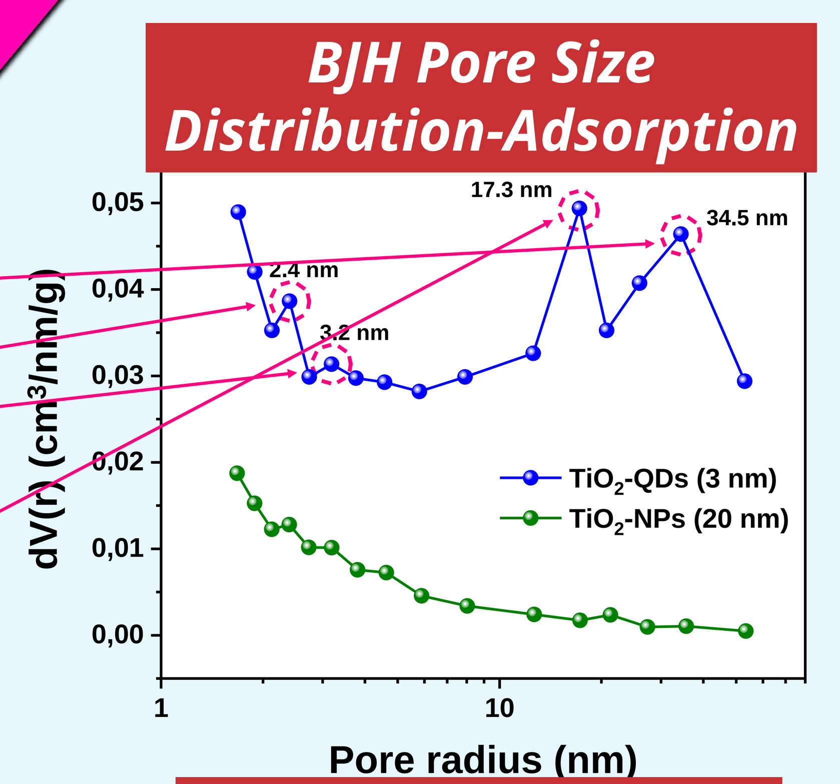


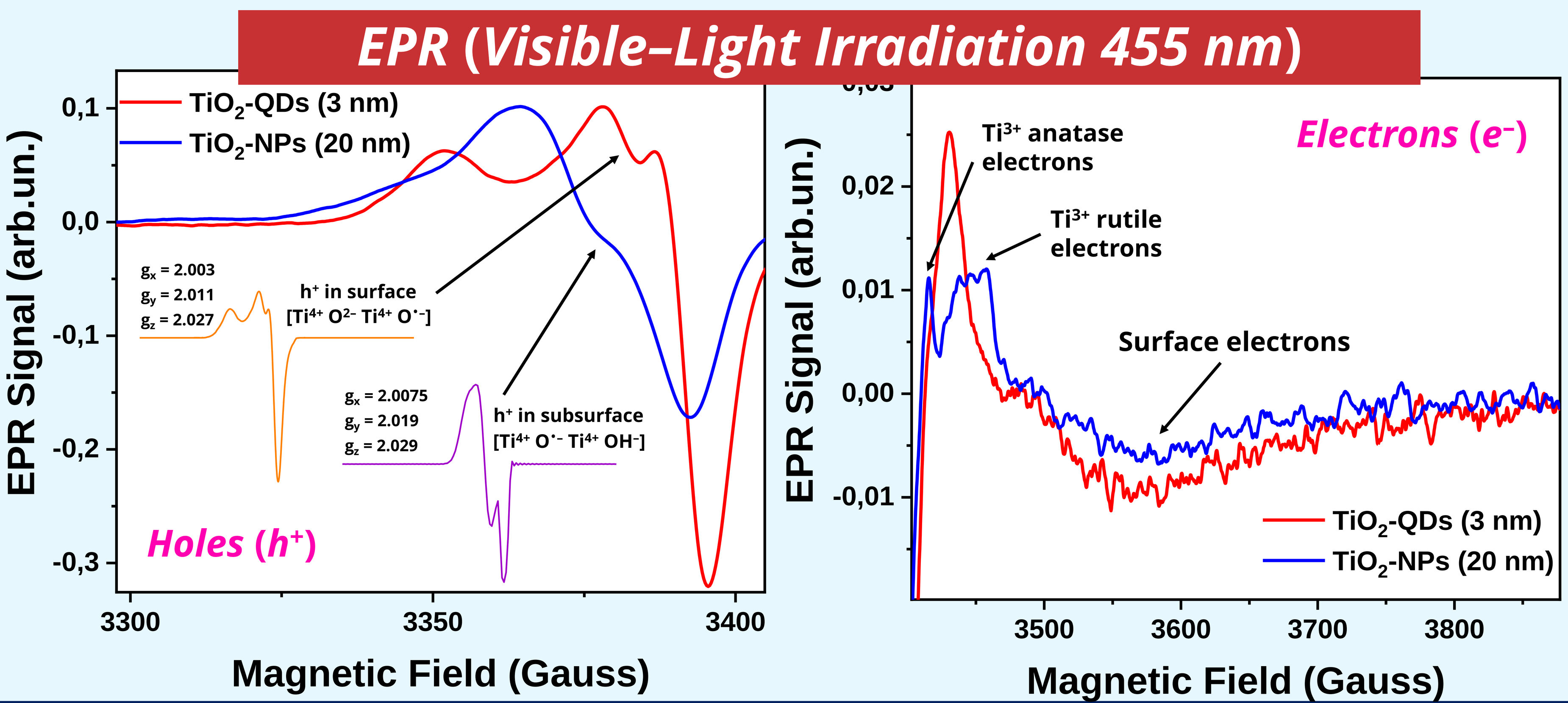


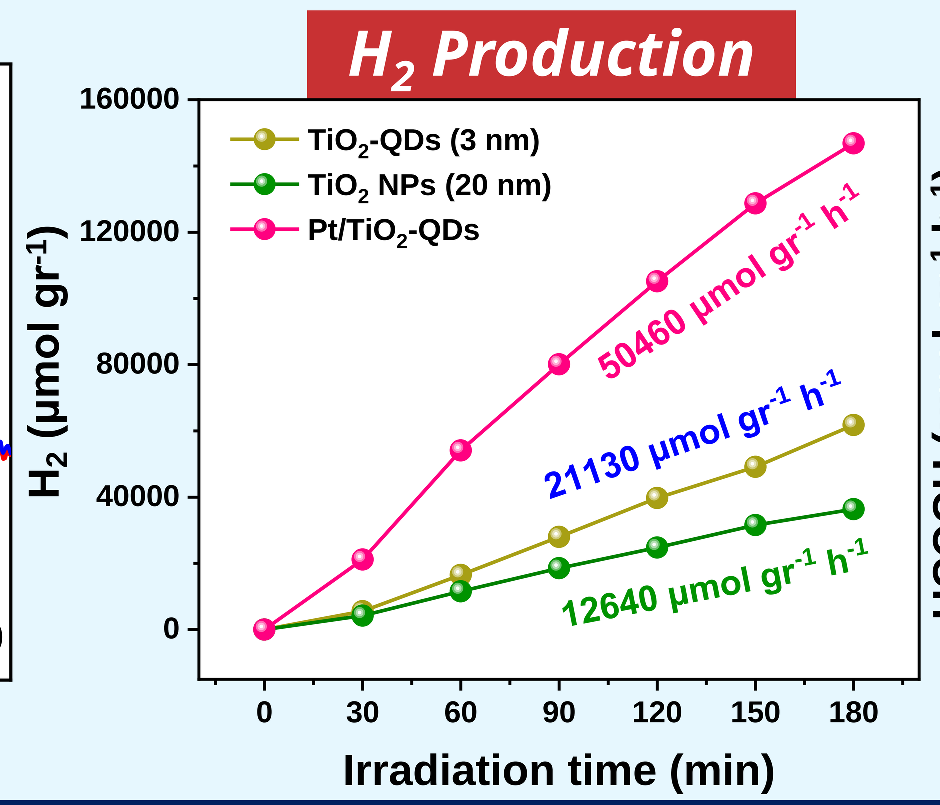


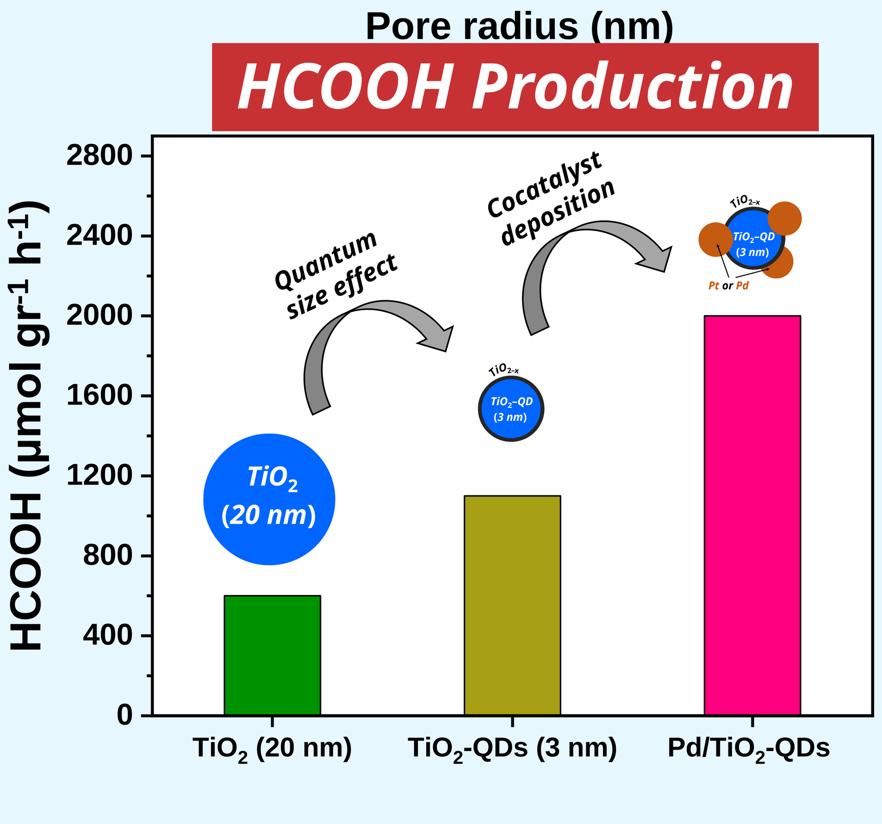












Conclusions

- TiO_2–QDs of 3 nm were synthesized and decorated with either 1% Pt or 1% Pd using the sequential FSP technology.
- Large pores of approximately 20 and 40 nm were formed; more effective desorption capacity.
- Surface dislocations; under visible light (455 nm), the electrons population was increased due to the quantum size effect on bandgap energy.
- Higher [SSA, porosity, surface electrons population]; the Pt/TiO_2–QDs and Pd/TiO_2–QDs display superior H_2 and HCOOH yield.

References

1) Satoh, N., Nakashima, T., Kamikura, K., & Yamamoto, K. (2008). *Quantum size effect in TiO_2 nanoparticles prepared by finely controlled metal assembly on dendrimer templates.* Nature Nanotechnology, 3(2), 106–111.
2) Lin, H., Huang, C., Li, W., Ni, C., Shah, S., & Tseng, Y. (2006). *Size dependency of nanocrystalline TiO_2 on its optical property and photocatalytic reactivity exemplified by 2-chlorophenol.* Applied Catalysis B: Environmental, 68(1-2), 1–11.
3) Brus, L. (1986). *Electronic wave functions in semiconductor clusters: experiment and theory. The Journal of Physical Chemistry, 90(12), 2555–2560.*
4) Deligiannakis, Y. (2018). *Nanomaterials for Environmental Solar Energy Technologies: Applications & Limitations.* KONA Powder and Particle Journal, 35(0), 14–31.
5) Howe, R. F., & Gratzel, M. (1985). *EPR observation of trapped electrons in colloidal titanium dioxide.* The Journal of Physical Chemistry, 89(21), 4495–4499.
6) Kočí, K., Obalová, L., Matějová, L., Plachá, D., Lacný, Z., Jirkovský, J., & Šolcová, O. (2009). *Effect of TiO_2 particle size on the photocatalytic reduction of CO_2.* Applied Catalysis B: Environmental, 89(3-4), 494–502.

We acknowledge support of this work by the project "*Center For Research, Quality Analysis Of Cultural Heritage Materials And Communication Of Science*" (MIS 5047233) which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Ευρωπαϊκή Ένωση Ευρωπαϊκό Ταμείο Περιφερειακής Ανάπτυξης · ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ ΥΠΟΥΡΓΕΙΟ ΟΙΚΟΝΟΜΙΑΣ & ΑΝΑΠΤΥΞΗΣ ΕΙΔΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΕΤΠΑ & ΤΣ ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ ΕΠΑνΕΚ · ΕΠΑνΕΚ 2014–2020 ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΑΝΤΑΓΩΝΙΣΤΙΚΟΤΗΤΑ ΕΠΙΧΕΙΡΗΜΑΤΙΚΟΤΗΤΑ ΚΑΙΝΟΤΟΜΙΑ · ΕΣΠΑ 2014-2020 ανάπτυξη - εργασία - αλληλεγγύη

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης