

## Introduction

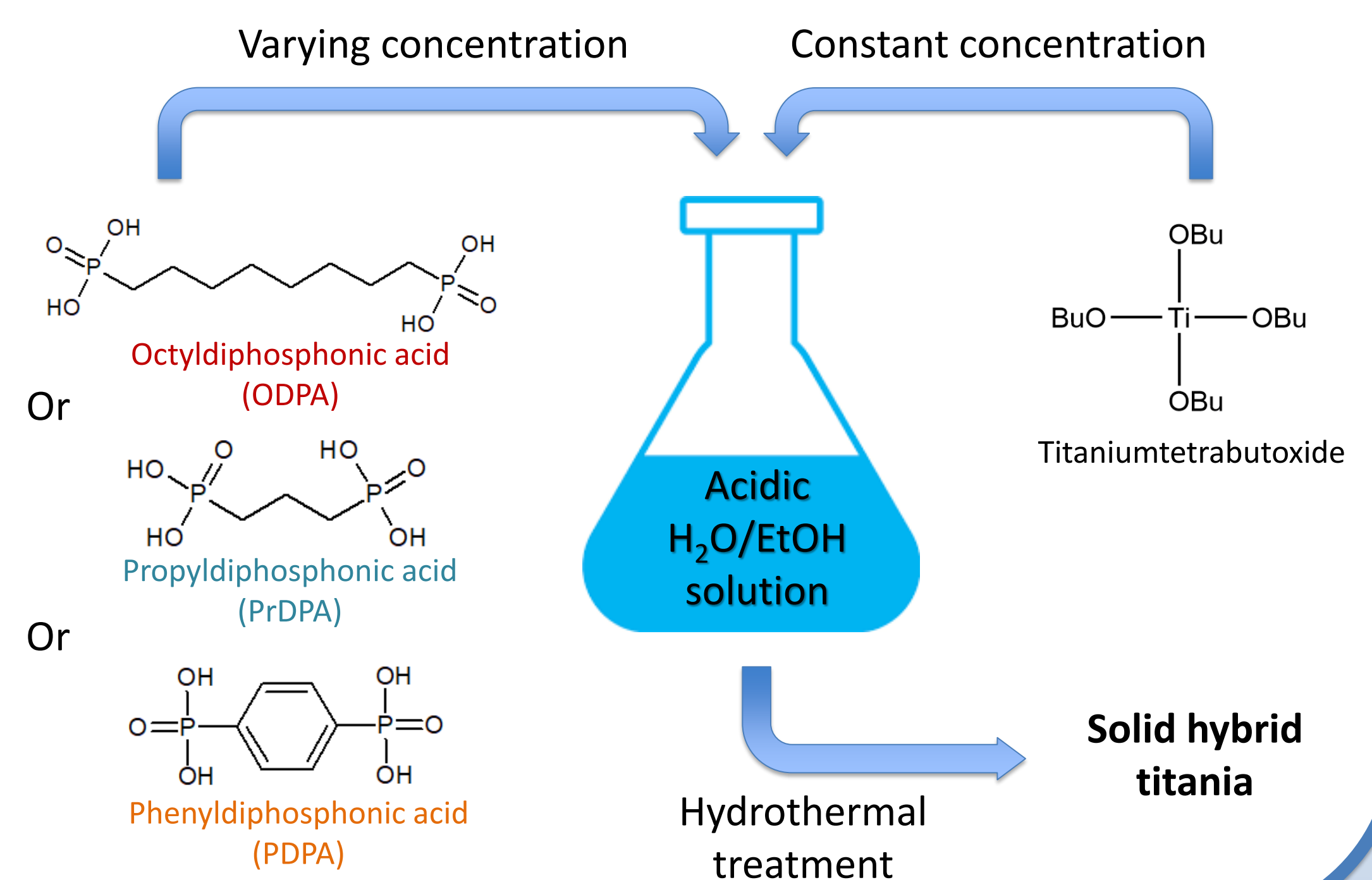
**What?** Hybrid materials aim to further enhance the properties of titanium dioxide (TiO<sub>2</sub>) via structural engineering with organic functionalities.

**Why?** Metal(IV) phosphonates have an excellent hydrolytic stability and stability to acids, which is lacking in silicate materials.

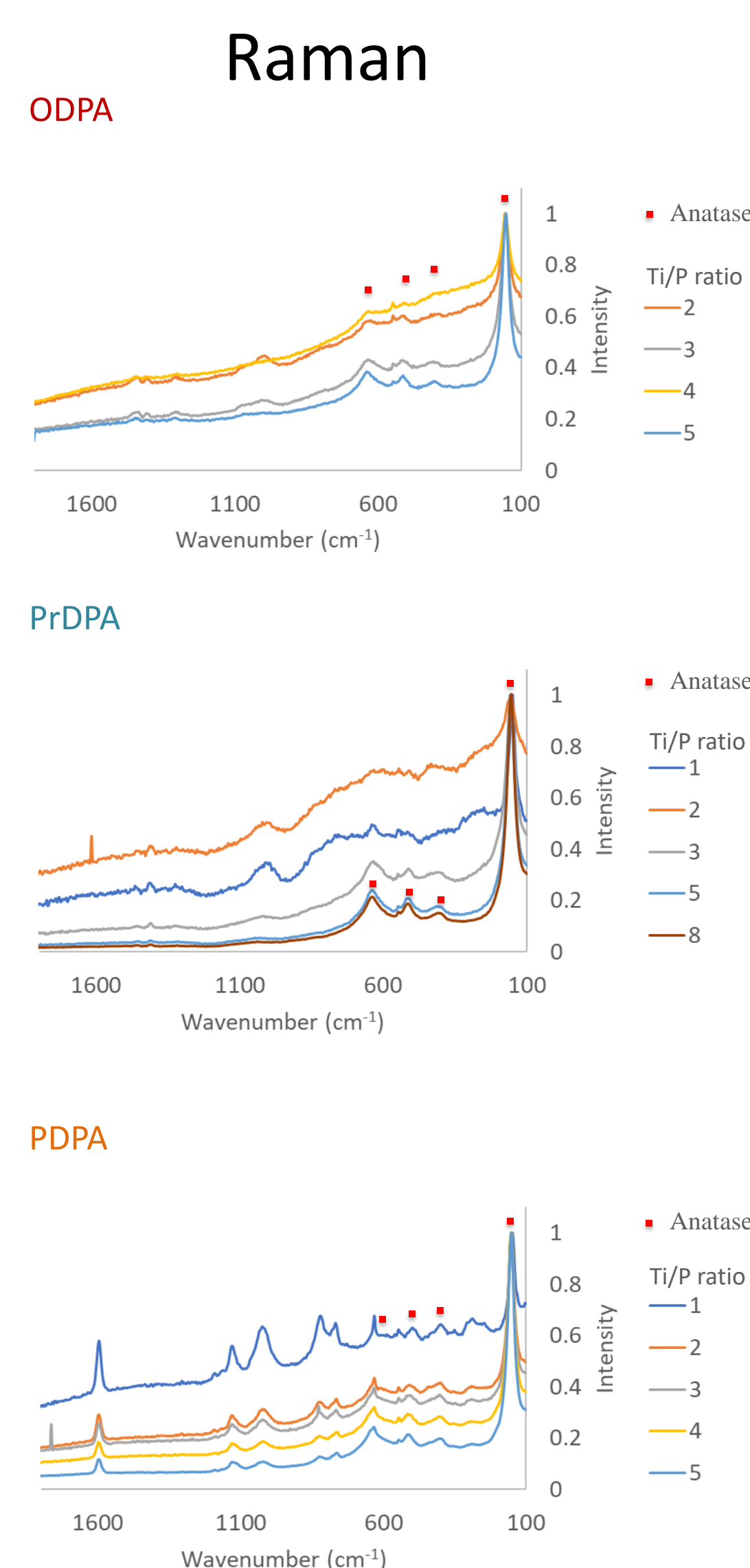
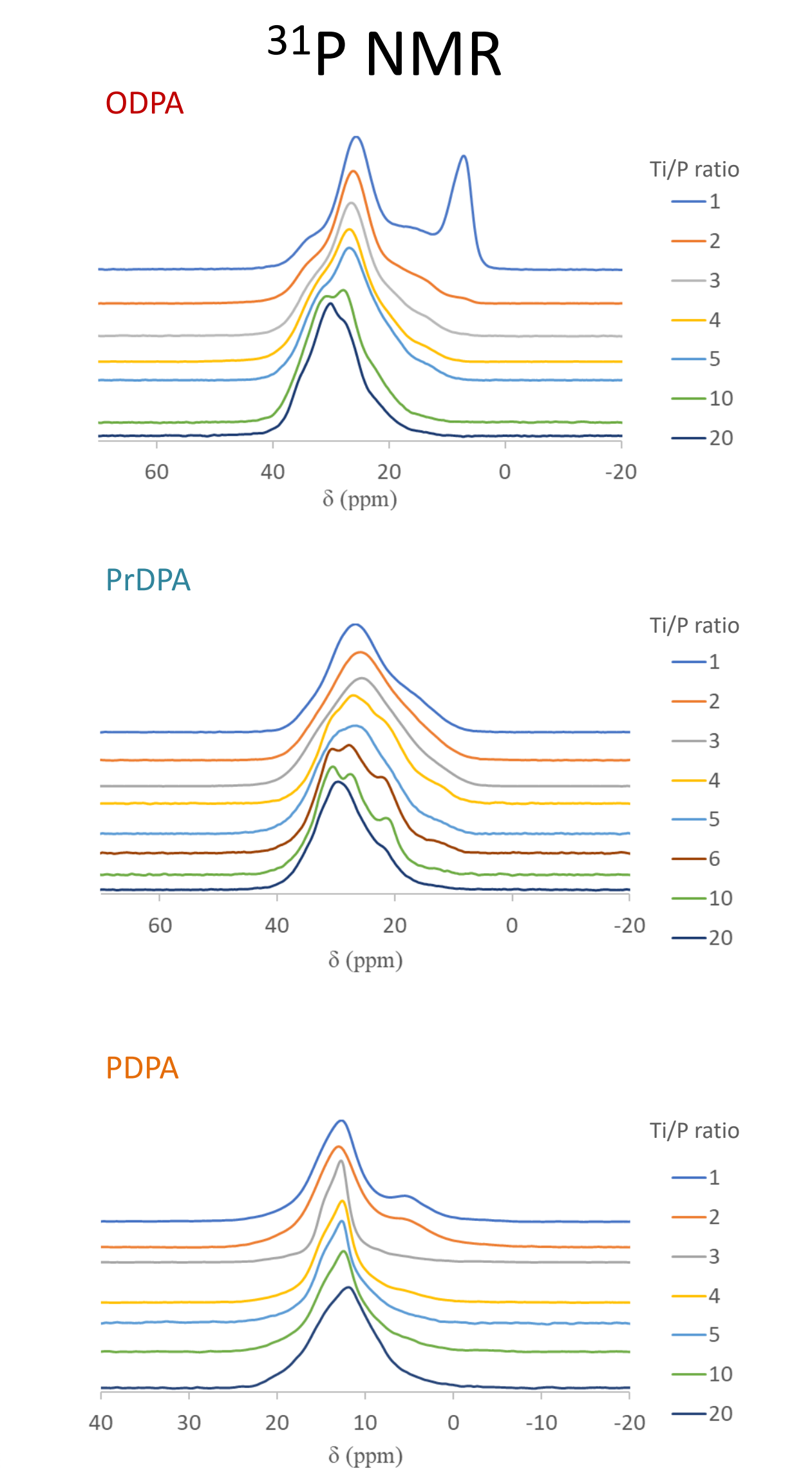
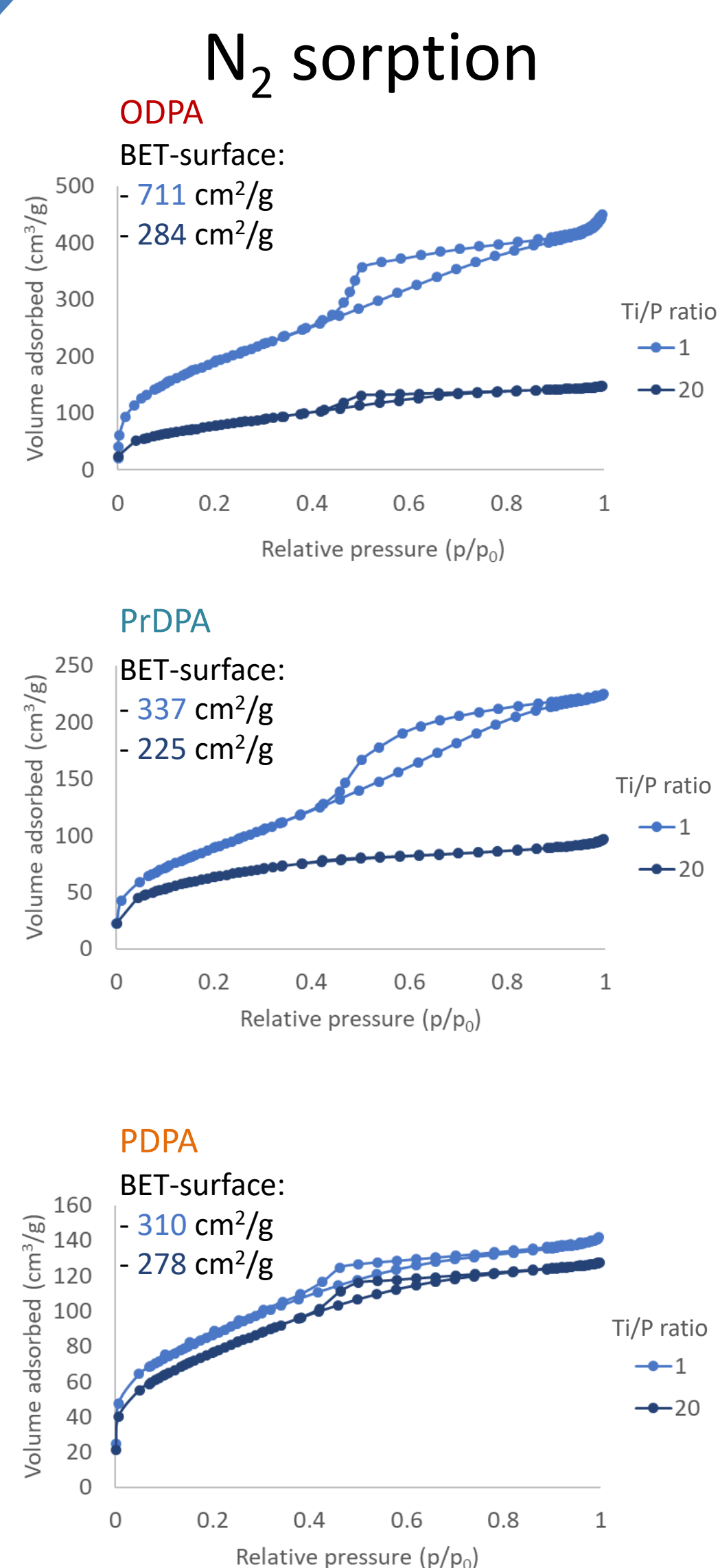
**Challenge?** Kinetic mismatch between different reactions leads to minimal control over the formed structures and their properties.

**Aim:** Investigate the influence of the Ti/P ratio and the organic group on the attained structure.

## Method



## Results



### ICP-OES

Theoretical Ti/P	ODPA
1	tbd
2	2.12
3	3.33
4	4.27
5	tbd

Theoretical Ti/P	PrDPA
1	1.31
2	2.03
3	3.33
4	tbd
5	5.13

Theoretical Ti/P	PDPA
1	1.09
2	2.60
3	3.08
4	4.19
5	5.18

- Type I(b)/IV isotherms with hysteresis confirm the presence of micro- and mesopores.
- Mesopore formation dependent on Ti/P ratio when alkylphosphonic acids are used.
- BET surface area between 225 and 711 cm<sup>2</sup>/g are observed.

- For low Ti/P ratio, Ti-O-P displays a peak around 26 ppm for alkyl chains, and 13 ppm for phenyl groups.
- Higher Ti/P ratios lead to a downfield shift of the main signal accompanied with an intensity change of the shoulders for alkylphosphonic acids.
- Layered titanium phosphonates are present in ODPA and PDPA.

- The anatase peak intensity increases upon lowering the phosphonic acid concentration, which signifies the incorporation of the phosphonic acid in the titania structure as its presence blocks the growth of anatase particles.
- PDPA hybrid materials have an increased tendency to form anatase at lower Ti/P ratios.

- Amount of incorporated material is generally correspondent with the theoretical Ti/P ratio.

## Conclusions

- Incorporation of the organic compound is successful as Ti-O-P bonds are formed.
- Incorporation of the phosphonic acid is complex and heavily depends on the Ti/P ratio.
- Structural control over porosity can be achieved by careful control of the Ti/P ratio and the choice of diphosphonic acid.
- Amount of organic moieties can be tuned by changing the Ti/P ratio

Future research will explore the adsorption behavior of the synthesized materials.

## References

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- Tassi, M. *et al.* A detailed investigation of the microwave assisted phenylphosphonic acid modification of P25 TiO<sub>2</sub>. *Adv. Powder Technol.* **28**, 236–243 (2017).

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