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Preparation of mesoporous bicrystalline N-doped TiO_2 nanomaterials for sustainable RhB degradation under sunlight

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Outline

- Introduction
- Methodology
- Result and discussion
- Conclusion
- Acknowledgment

Introduction

- Water is the prime necessity for *all living beings.*
- It covers 75% of the earth's surface, less than 1% of these can be utilized as drinking water….
- A growing *number of toxic contaminants* are being discharged to water supplies in *both developing* and *industrialized nations*.

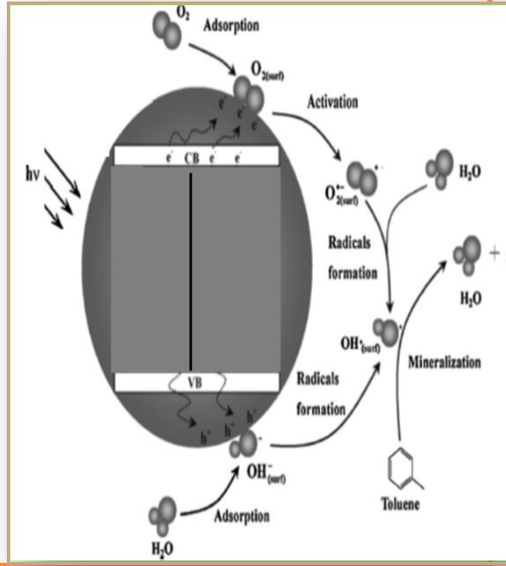
The Promising material, Photocatalyst

- Photocatalysts have received significant attention
  - ✓ are material can perform light-induced chemical reactions

    e.g. TiO_2, Fe_2O_3, ZnO, WO_3, CdS and $SrTiO_3$

- The advantages of nano-photocatalysts over conventional
  - ✓ high specific surface area
  - ✓ faster adsorption equilibrium
  - ✓ small diffusion resistance
  - ✓ high retention reusability character
  - ✓ Use the cheapest source of energy, Sunlight

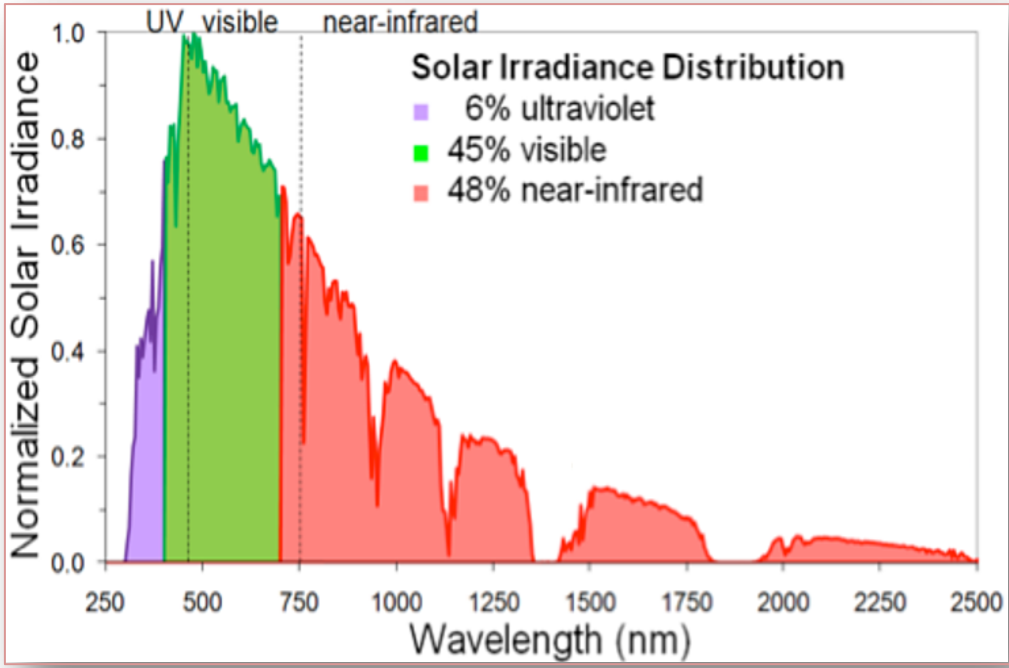
❖ How it works…



Con't…

- TiO_2 is the most dominant and promising, due to
  - chemically stable, photostability
  - nontoxic, abundant and cheap
  - suitable band alignments

- Commercially as P25 (Degussa)
- However, TiO_2 owns
  - ✓ large band gap- needs UV
  - ✓ low solar energy usage
  - ✓ slow charge mobility
  - ✓ high recombination rate
- Limits its practical applications



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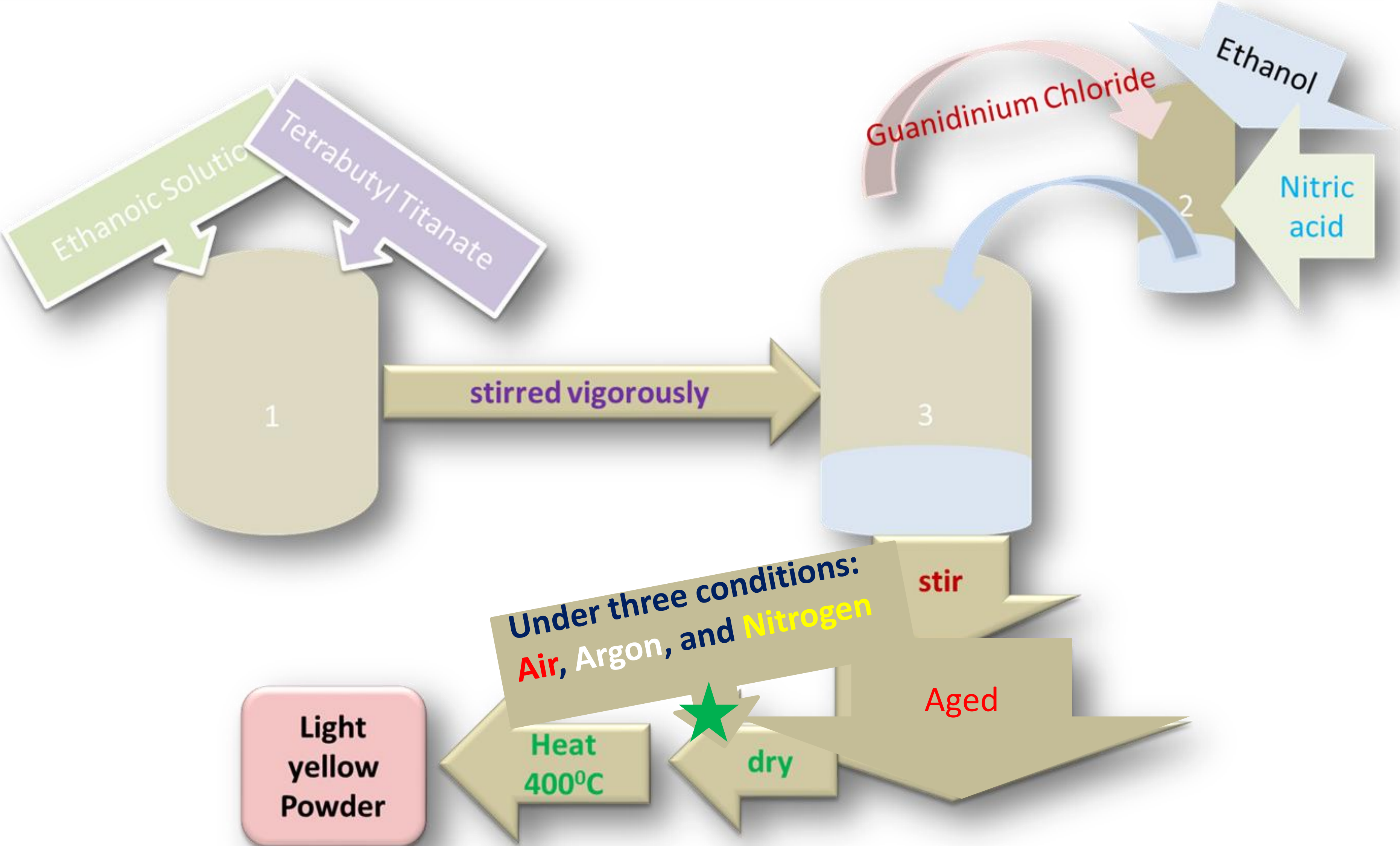
- The development of visible light TiO_2 photocatalyst
  - Band Gap Engineering… Eg. doping, coupling, Sensitizing
  - Surface Engineering… Eg. defect formation

❖ The main research focus are

- ✓ To prepare visible active N-doped TiO_2 nanomaterial
- ✓ To study the **effect of annealing gas type** on physicochemical properties and photocatalytic active against Rhodamine B (RhB)

Preparation Methodology



Result and Discussion

XRD

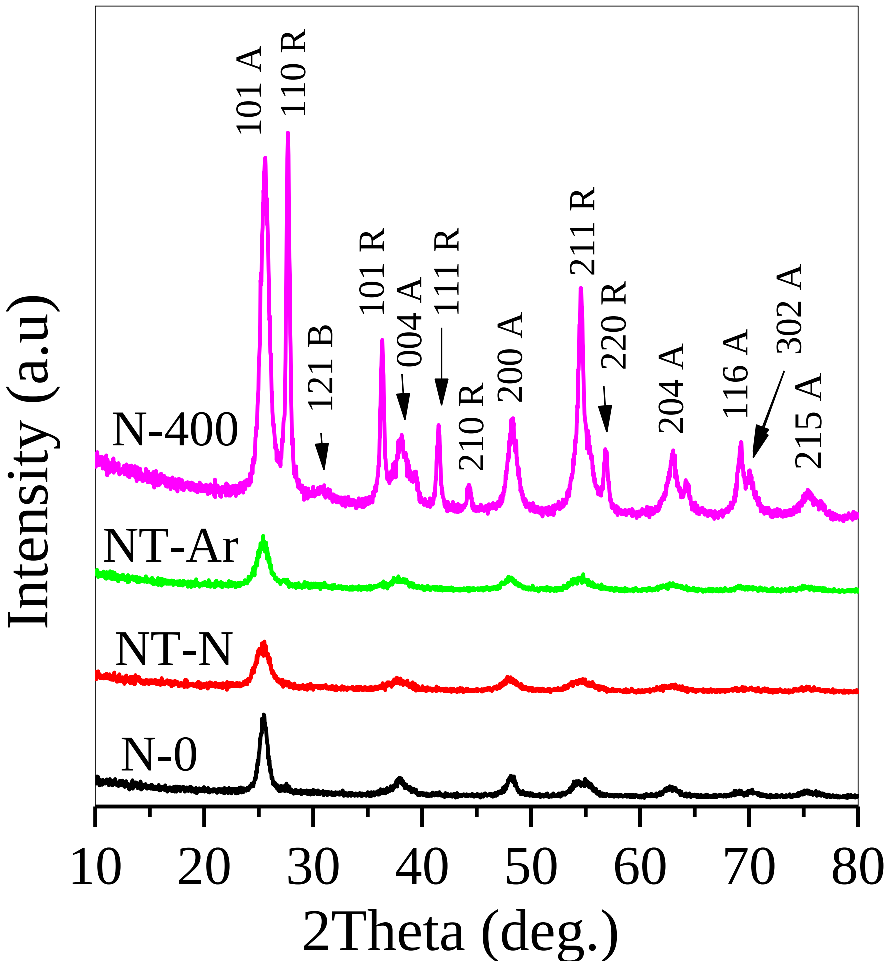


Figure 1 XRD data of as-prepared nanomaterials (A: anatase, R: rutile).

- Both **NT-Ar** and **NT-N** (which were prepared in Ar, and N_2 gas, respectively) have **98% anatase phase** (JCPDS: 21-1272) like N-0.
- Whereas **NT-A**, which was prepared in atmospheric air, has a mixture of **53% anatase** and **44% rutile phases**.
- The difference in gas environment influences the degree of crystallinity and particle size.

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Morphology

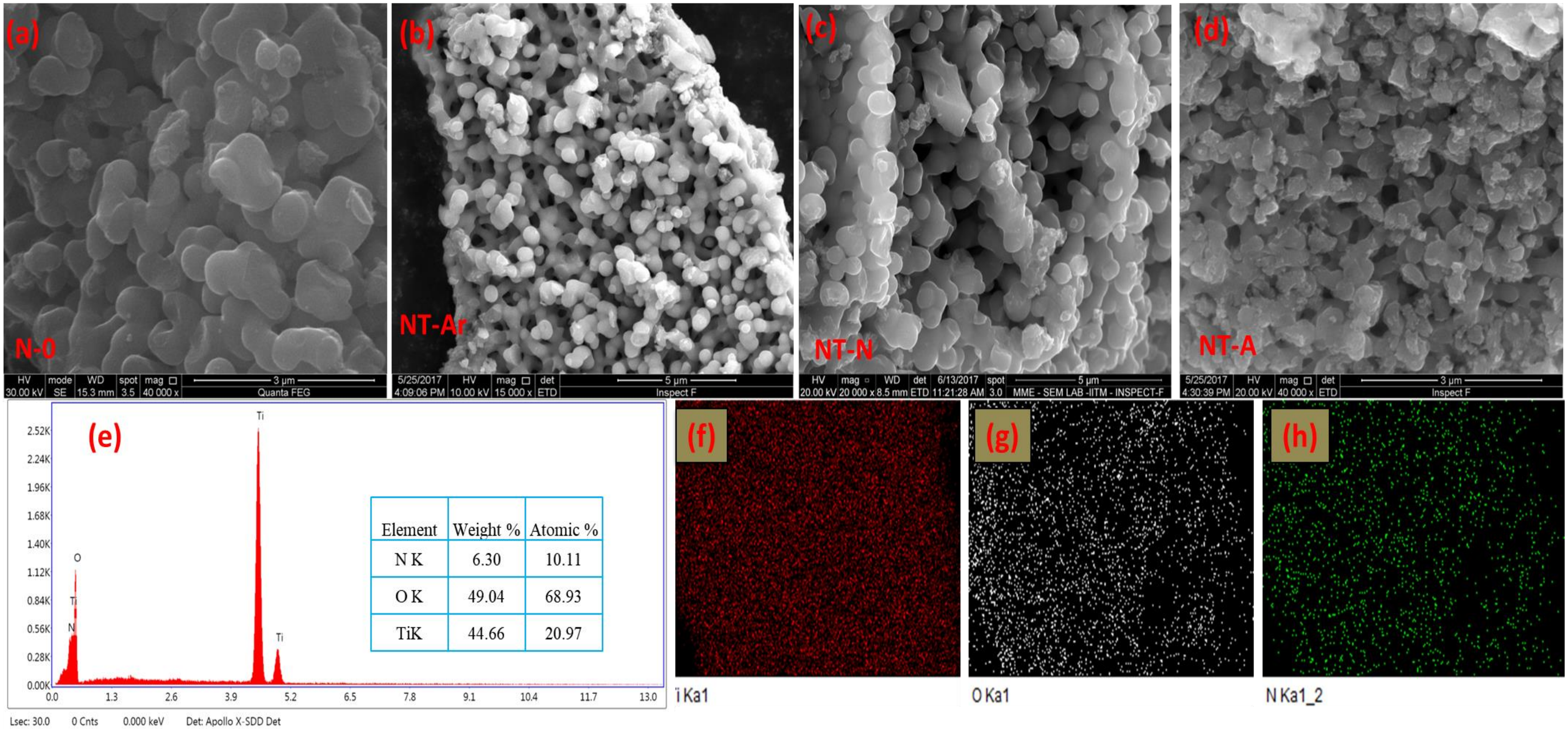

Figure FESEM images of N-0 (a), NT-Ar (b), NT-N (c), NT-A (d); and EDAX of NT-A (e) with its elemental mapping of Ti (f), O (g), N (h).

- N/TiO_2 has a spherical shape with some aggregation
- N was effectively doped and homogeneously distributed in the crystal

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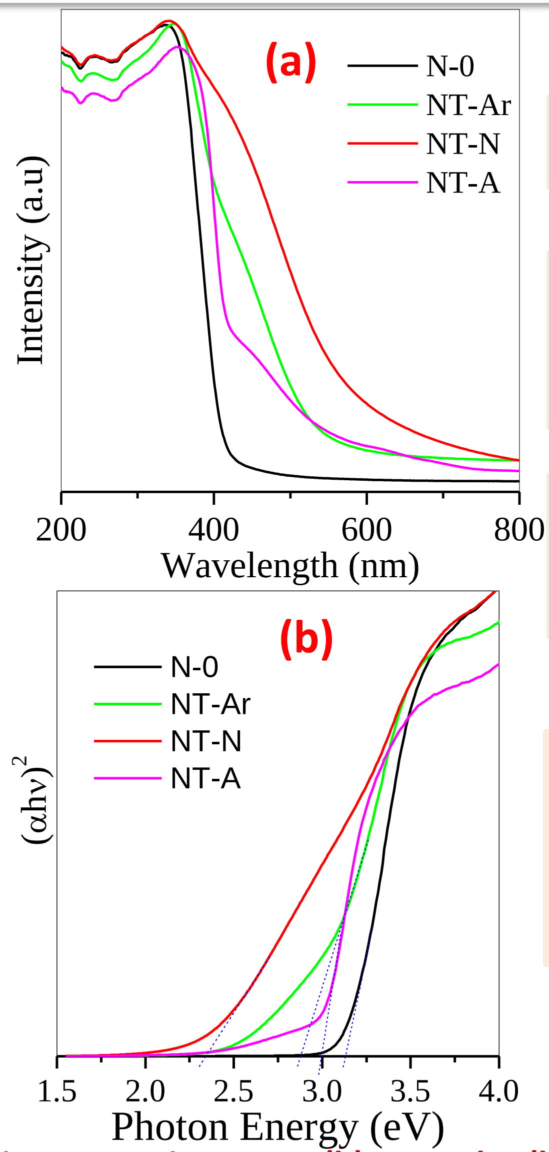

Optical response

- The N-0 absorbs in the UV region (~ 400 nm).
- The N/TiO_2 have two peaks: at ~ 420 nm, and 420-600 nm, enhancing their visible absorption
- The N/TiO_2 samples showed a red shift unlike the undoped.
- K-M plot (b) all the N/TiO_2 materials exhibited lower band gap energy than TiO_2; NT-N particularly demonstrated the lowest of 2.35 eV.

Figure UV-Vis spectra (b), K-M plot (b) of obtained N/TiO_2 nanomaterials.

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Photoluminescence

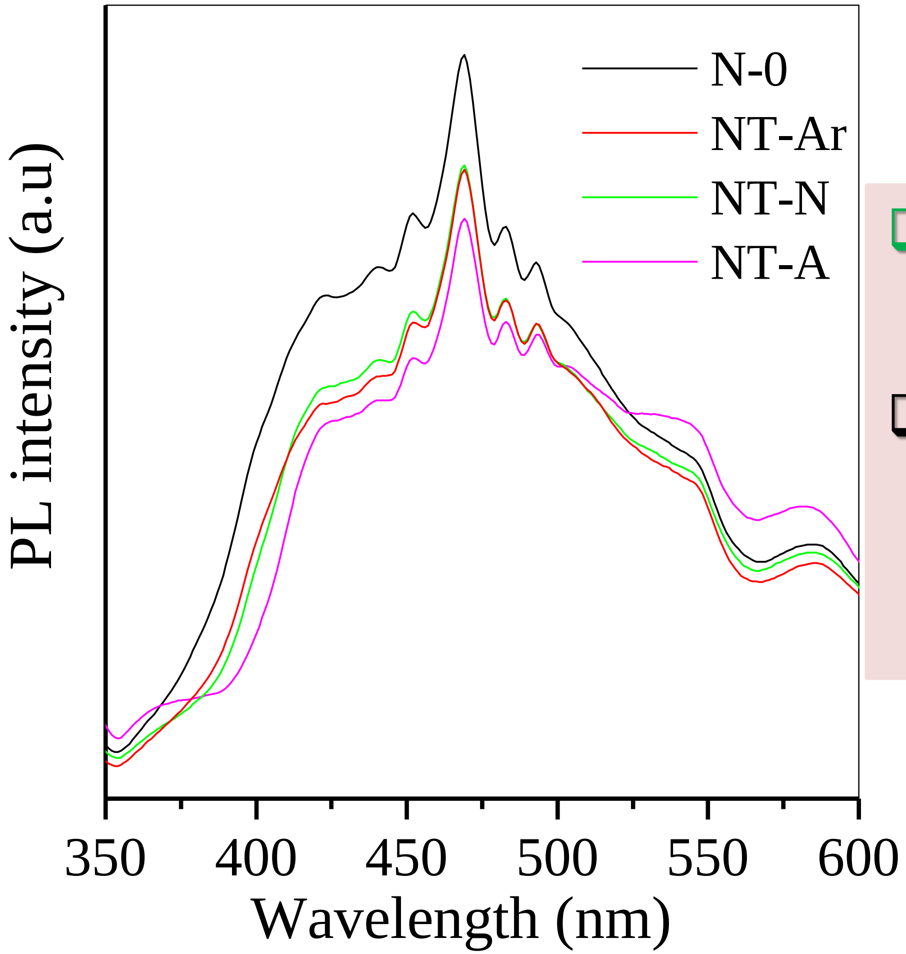
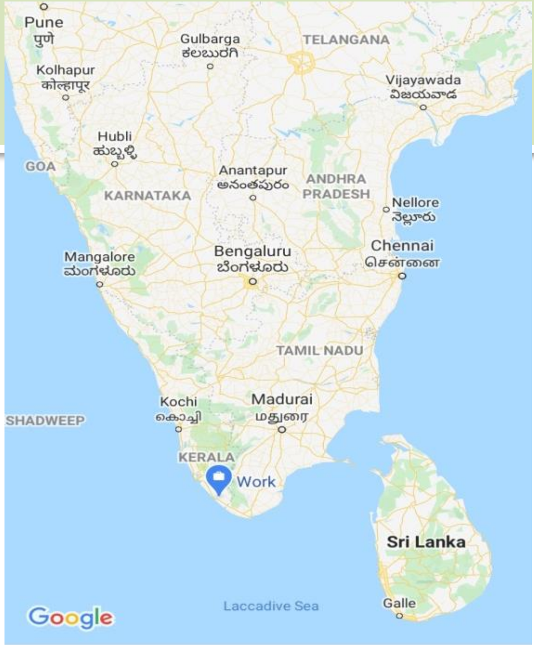


Figure Photoluminescence spectra of obtained N/TiO_2 nanomaterials.

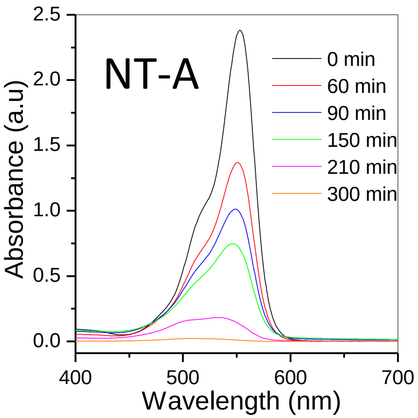
- All the N/TiO_2 samples have lower PL peak than the pure TiO_2
- revealing the introduction of the N species in the TiO_2 crystal lowers the photo-generated charge carriers' recombination rate

Photocatalytic Activity



- **<u>Conditions:</u>**
  - ➢ Catalysts Weight: 50 mg
  - ➢ Rh B Concentration: 20 ppm
  - ➢ MB Volume: 200 mL
  - ➢ Light Source: Sun light irradiation at CSIR-NIIST Trivandrum (8°31' N, 76°56' E) the month of *January* (having Solar irradiance ~ 240 W m^{-2}, Temp. 25.5 °C, and 66.5% humidity)
  - ➢ Photoreaction Time: 30 min adsorption and 5 Hrs (11 AM to 4 PM)

NB: The change in the characteristic absorption band of **Rh B 552 nm** was used to calculate the photodegradation efficiency



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Photocatalytic Activity

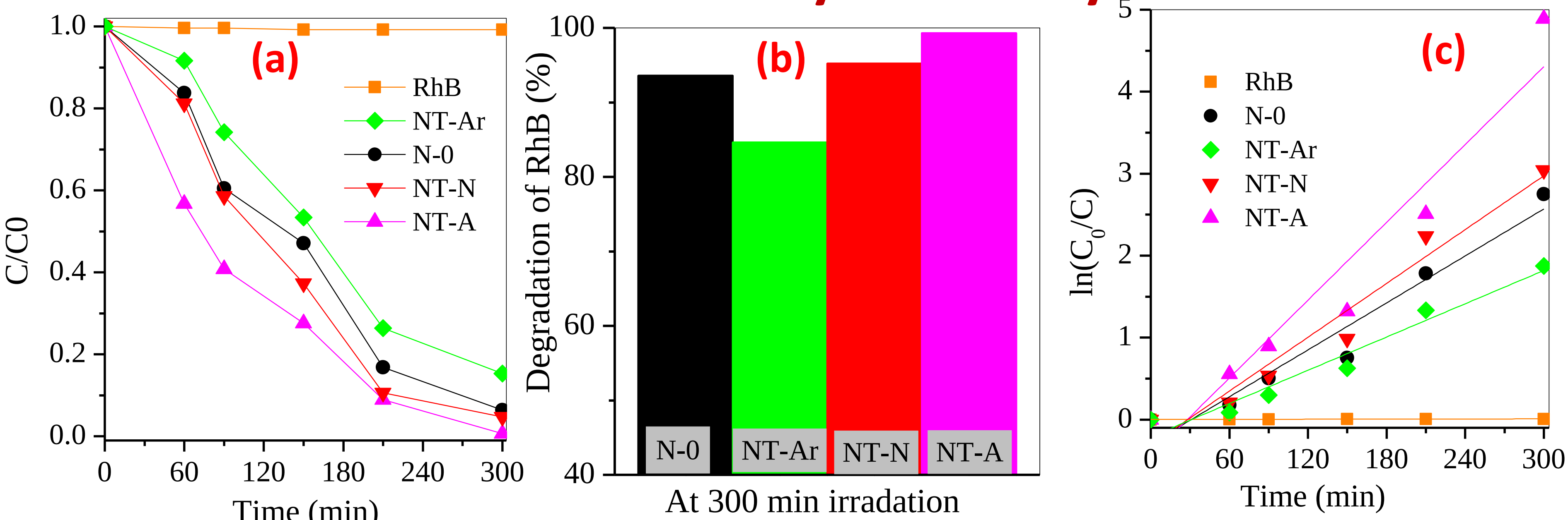

Figure (a) RhB degradation rate under sunlight; (b) RhB photodegradation performance under 300 min irradiation; (c) pseudo first order of as-synthesized catalysts

- The concentration and characteristic RhB peak intensity are reduced as the function of irradiation time.
- Particularly, NT-A (the catalyst annealed in air) displayed the highest photocatalytic efficiency (99%) within 300 min sunlight irradiation.
- The RhB degradation performance was in the following order:

  NT-A (in air) > NT-N (in nitrogen) > N-0 > NT-Ar (in argon)

Conclusion

- The N/TiO_2 powders were optimized at different annealing gas types (air, argon, nitrogen) which profoundly influenced their physicochemical and photocatalytical properties.
- Notably, the sample prepared in air demonstrated the highest degradation performance (99%) with the highest apparent rate constant (0.0158 min^{-1}) which is twice faster than the undoped TiO_2.
- Such outstanding performance is attributed to the synergistic effect of N doping and its optimal anatase/rutile phase which led to higher specific surface area, higher light absorption capacity, lower band gap energy, and lower charge carriers recombination.
- Such visible active dual phase N/TiO_2 photocatalysts will have practical applications in photocatalysis, photoelectrochemical, and photoelectric areas.

Acknowledgment

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