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Recent Advances of Modified TiO_2 Nanostructure as Heterogeneous Catalyst in Organic Transformations

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Abstract: *This review highlights the different strategies of modified TiO_2 nanostructure as heterogeneous catalyst in organic transformations. The modification in TiO_2 nanostructure have been achieved by doping with metal and non-metal, composing with other material such as metals, metal oxides, nonoxides, semiconductor and nanostructure carbon materials. The influence of modification in TiO_2 nanostructure on catalytic properties in organic synthesis also discussed. Different modifications of TiO_2 extend the catalyst selectivity and reusability over unmodified TiO_2 nanoparticles. Recent investigations have shown that modified TiO_2 nanostructures utilised as active catalysts or catalyst support in organic transformations including C-C, C-N, C-S, C-O bond formation reactions, multicomponent reactions (MCR), oxidation- reductions.*

Keywords: Heterogeneous Catalyst, TiO_2 Nanoparticles, Organic Transformations, TiO_2 as Support, Supported Nanoparticles

I. INTRODUCTION

This A rapid industrialization and urbanization have produced many serious environmental issues during past few decades.[1,2] Therefore researchers have been faced with a new challenge of finding the environment-friendly processes that can reduce or eliminate the dependence of hazardous reagents and solvents. 'Heterogeneous catalysis' is one of most powerful approach to replace or eliminate polluting processes.[3] Heterogeneous catalysis long established in commercial production of fuels, polymers and fibers. In recent years considerable interest has been developed towards the use of the heterogeneous catalyst in the synthesis of advanced intermediate, fine chemicals, and bioactive heterocyclic compounds.[4,5]

Heterocyclic compounds are an important and largest division of organic compounds and played a significant role in the pharmaceutical, agricultural, biological etc. field as they show broad spectrum of biological activity.[6-7] A variety of conventional catalysts were used for synthesis of heterocyclic compounds. However, these protocols suffered one of the drawbacks such as a necessity of excess organic solvent, needs longer reaction time, tedious work up procedures and recovery of catalyst.[8] The solid catalyst was used as a heterogeneous catalyst due to their easy separation and reusability.

Metal oxides are a versatile class of solid catalyst widely utilized in organic/inorganic transformations, water treatment and removal of pollutants.[9-11] In recent years, (TiO_2) have been paying much more attention due to high chemo-selectivity, environmental compatibility, thermal stability and low cost.[12] In past several reports reviewed on TiO_2 based nanomaterial in numerous areas, including medical research, drug delivery, antibacterial materials, energy storage, self-cleaning and.as a catalyst in organic reactions such as condensation, dehydrogenation, hydrogenation, dehydration, and coupling reactions.[13-14] It is widely demonstrated that the physical and chemical modification in TiO_2 were achieved by controlling the particle size to nanometer scale. [15]

Nanocrystalline materials are polycrystalline solids with a grain size of a few nanometers, typically < 100 nm. Nanocrystalline materials are a new class of materials that display distinct electrical, optical, magnetic, catalytic

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properties over their bulk counterparts. These features of nanocrystalline material have great impacts in various fields.[16] Nanocrystalline TiO_2 are exceptionally important oxides having applications in preparing gas sensors, electrical devices, fuel cells, piezoelectric devices, chemical absorbent, optical devices, varistors and catalyst.[17-19] The properties nanocrystalline materials can be rationalized by adopting various synthesis and post-synthesis routes.[20,21] Furthermore, it is possible to confirm these modifications by the available characterization techniques. Therefore, development of a morphologically controllable synthesis of nanocrystalline metal oxides by a simple and economical method is an important research

1.1 TiO_2

Titanium dioxide (TiO_2) is naturally occurring oxides, was discovered in 1795 and commercial production started in the 1920s.[22] TiO2 powders possess distinctive optical, electrical and catalytic properties. Hence, it is extensively used in paints, paper, textiles, plastics, inks, anti-bacterial agents, corrosion-resistant coatings, water and air purification, self-cleaning surfaces, rechargeable batteries, food additives sensor devices, etc[23,25] In 1972, Fujishima and Honda revealed the photochemical splitting of water into hydrogen and oxygen with TiO_2, that led to great attention towards TiO_2 as heterogeneous photo-catalyst.[26] Its properties in the visible and UV portions of the electromagnetic spectrum are especially significant.

1.2 Nanocrystalline TiO_2

The interest in nanocrystalline TiO_2 have been grown extensively due to their outstanding chemical and physical properties, which furnished wide their applications such as optics, sensors, catalysts, pigments photovoltaic cells, photocatalysts. TiO_2 is known for its easy availability, low cost, prolonged chemical stability and nontoxic nature .The use of nanocrystalline TiO_2 in variety of applications was attained by fulfilling requirements in terms of particle size, size distribution, morphology, crystallinity and phase.[13] The desired property of TiO_2 can be achieved by adapting proper synthetic method and reaction condition.[14]

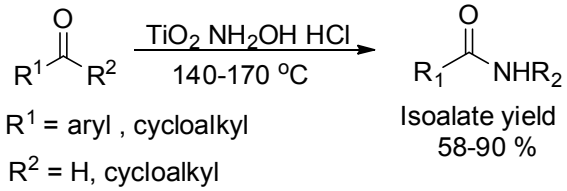
II. Significance of Nanocrystalline TiO_2 in Organic Transformation

2.1 Bare TiO_2 Nanoparticle as Heterogeneous Catalyst

2.1.1. Beckmann Rearrangement

Beckmann rearrangement involves conversion of ketoximes or aldoximes into corresponding amides. It is significant route particularly for manufacturing ε-caprolactam in the chemical industry. Beckmann rearrangement are usually carried out in presence of strong Lewis or Bronsted acid such as sulfuric acid, phosphorus penta chloride, hydrochloric acid in presence of organic solvents. These routes leads to formation of variety of by-product.

Sharghi, H. *and et al.* examined the TiO_2 as solid catalyst for Beckmann rearrangement of several ketones and aldehydes. It was found ketones and aldehydes reacts NH_2OH. HCl to give corresponding amides in single step with quantitative yield under solvent free condition.[26] Solvent free condition, simple work-up, use of commercial, available and inexpensive catalyst and high yields, can make this procedure a useful and attractive alternative to the currently available methods.



Scheme 1: Beckmann rearrangement

2.1.2 Strecker Reaction

Seyed Meysam Baghbanian *et al.* developed a simple and efficient for the synthesis of α-amino nitriles from aldehydes, amines and trimethylsilyl cyanide (Me_3SiCN) in the presence of a catalytic amount of cyanuric acid at room temperature.[28]

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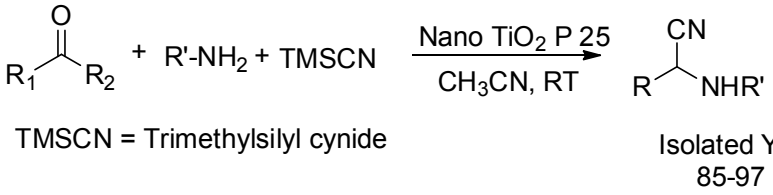


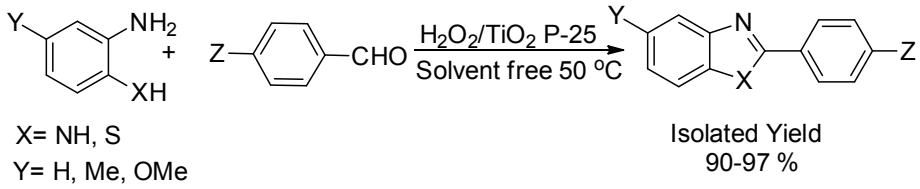
Scheme 2: Strecker reaction in malononitrile

Entry	Catalyst (mol%)	Time (min)	Yield[b] (%)
1	No catalyst	12 h	0
2	5	10 min	55
3	10	10 min	70
4	20	10 min	98
5	25	10 min	98
6	20	15 min	86[c]
7	20	25 min	90[d]

TiO_2 P 25 was added to a mixture of 1 mmol of benzaldehyde, 1 mol of aniline, and 1.2 mmol of TMSCN. [b] Isolated yield. [c] In the presence of $CHCl_3$. [d] In the presence of THF.

2.1.3 Synthesis of Benzimidazole

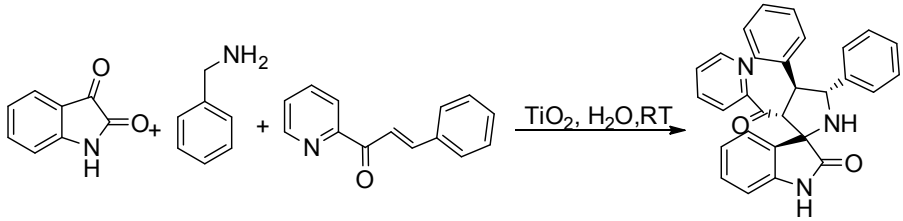
Bahram, K. and *et al.* described an oxidative coupling of *o*-phenylendiamine /*o*-aminothiophenol and aromatic aldehydes were carried out in presence of H_2O_2/TiO_2 P-25 NPs (particle size ≈ 21 nm) afford 2-substituted benzimidazole and benzothiazole derivatives (**Scheme 3**).[29] It was observed that the absence of TiO_2-P25 NPs reaction proceeded very slowly and reaction stopped to formation of imine derivatives, In contrast, the presence of catalytic amount of TiO_2-P25 NPs leading to formation of desired products. The catalyst can be activate the decomposition of H_2O_2. The reaction condition tolerates to both aldehydes bearing electron-withdrawing and electron-donating substituents in excellent yield the desired product. However, the same optimum reaction condition did not give desired 2-substituted benzoxazoles by reaction between 2-aminophenol and aldehydes. The catalyst TiO_2-P25 NPs is stable and reused upto the 5 consecutive runs without considerable loss of catalytic activity.



Scheme 3: Synthesis of benzimidazoles

2.2.4. Synthesis of Spiroxindole-Pyrrolidine

Pambal Ramesh and *et al.* reported TiO_2 NPs as a reusable heterogeneous catalyst for synthesis of spiroxindole-pyrrolidine by reacting of 3-aryl-1-(pyridin-2-yl)-prop-2-en-1-one, isatins and benzylamines *via* 1,3-dipolar cycloaddition reaction using water as reaction media.[30]



Scheme 4: Synthesis of spiroxindole-pyrrolidine by reacting of 3-aryl-1-(pyridin-2-yl)-prop-2-en-1-one,

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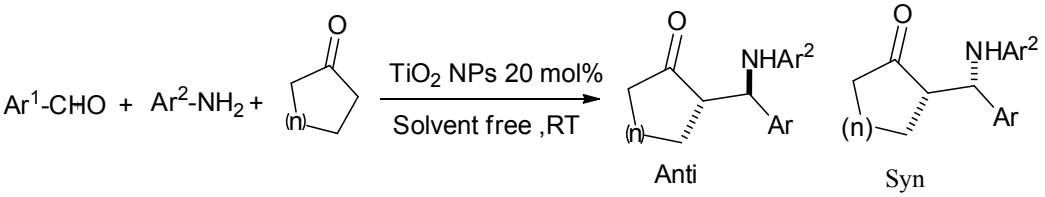
2.2.5. Mannich Reaction

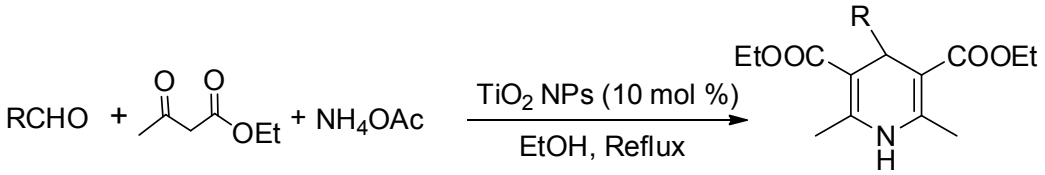
M.Z. Kassaee and *et al.* synthesized spherical shaped pure anatase TiO_2 NPs *via* a sol–gel method. The as synthesized catalyst was used for synthesis of β-aminocarbonyl *via* mannich reaction. It was observed TiO_2 nanoparticle catalysed n under solvent free condition[31].



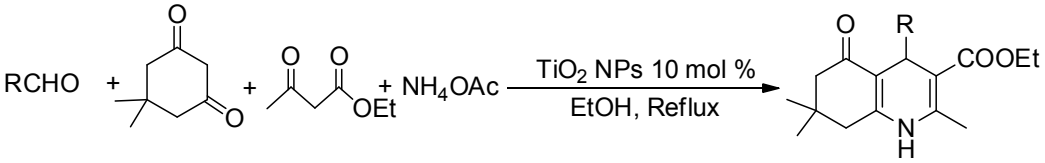
Scheme 5: Preparation of β-aminocarbonyl compounds

2.4.6. Hantzsch Condensation

1,4-Dihydropyridine and polyhydroquinoline derivatives have been prepared efficiently in a one-pot synthesis *via* Hantzsch condensation using nanosized titanium dioxide as a heterogeneous catalyst[32]. The present methodology offers several advantages such as excellent yields, short reaction times (30–120 min) environmentally benign, and mild reaction conditions. The catalyst can be readily separated from the reaction products and recovered in excellent purity for direct reuse.



Scheme 6a: One-pot synthesis of 1,4-DHPs. NPs-nanoparticles



Scheme 6b: One-pot synthesis of polyhydroquinoline derivatives

Table 2: The efficiency of several classical solvents

Entry	Solvent	Temperature (°C)	Time (h)	Yield[a] (%)
1	—	25	6	60
2	—	80	6	68
3	CH_2Cl_2	reflux	6	35
4	CH_3CN	reflux	6	45
5	toluene	reflux	6	50
6	H_2O	reflux	6	30
7	H_2O + EtOH	reflux	6	42
8	EtOH	reflux	1.75	92
9	EtOH	40	6	78
10	EtOH	25	4	45

[a]Yield refers to isolated products.

2.5.7. Synthesis of 1,8-dioxo-Decahydroacridine Derivatives

Ardeshir Khazaei and *et al.* studied effect of the rutile and anatase TiO_2 phases for synthesis of 1,8-dioxo-decahydroacridine derivatives under solvent-free condition[33].

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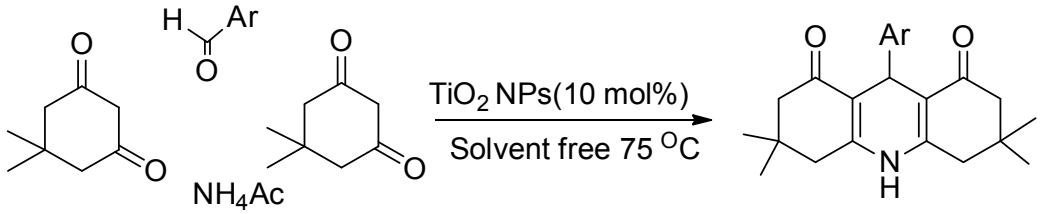
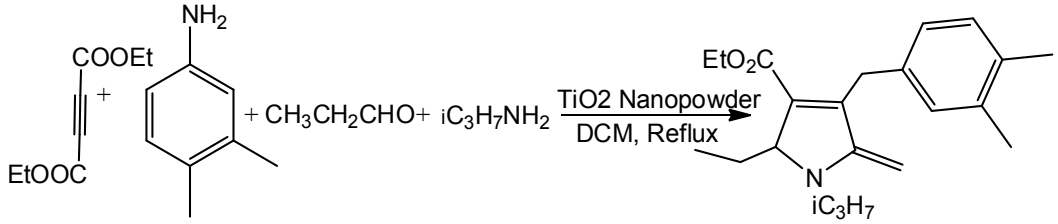


Scheme 7: One-pot synthesis of polyhydroquinoline derivatives

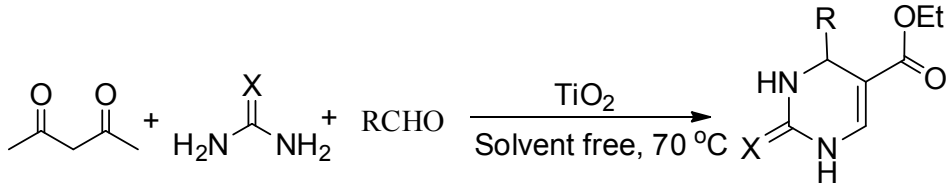
2.2.8. Synthesis of substituted 2- oxo dihydropyrroles

Sunil Rana and et al. demonstrated site-selective multicomponent synthesis of substituted 2- oxo dihydropyrroles catalyzed by heterogeneous TiO_2 nanopowder[34]. The reaction is site-selective with respect to aromatic and aliphatic amines. Environmentally benign reaction procedure, excellent yields, tolerance of varieties of functionalities in the reactants, a wide variety of products and reusability of the catalyst make the methodology highly beneficial for the synthesis of polyfunctional dihydropyrroles.



Scheme 8: TiO_2 nanopowder catalyzed multicomponent synthesis of fully substituted dihydropyrroles

2.1.9 Bigilini Reaction



Scheme 9: TiO_2 nanopowder catalyzed Bigilini reaction

Table: Screening of catalysts for the synthesis of multifunctional dihydropyrroles

Entry	Catalyst (10 mol %)	Isolated yield (%)	Time (h)
1	Boric acid + glycerol (1 drop)	60	12
2	$FeCl_3$	46	12
3	TsOH	58	12
4	AcOH	65	12
5	SiO_2	37	12
6	Al_2O_3 (acidic)	31	12
7	H_3PO_4–SiO_2	66	12
8	$H_3PW_{12}O_{40}$	78	12
9	Commercial TiO_2 (10)	83	12
10	TiO_2 nanopowder (10)	91	12
11	TiO_2 nanopowder (5)	82	12
12	TiO_2 nanopowder (15)	90	12
13	TiO_2 nanopowder (10)	91	3
14	None	Trace	12

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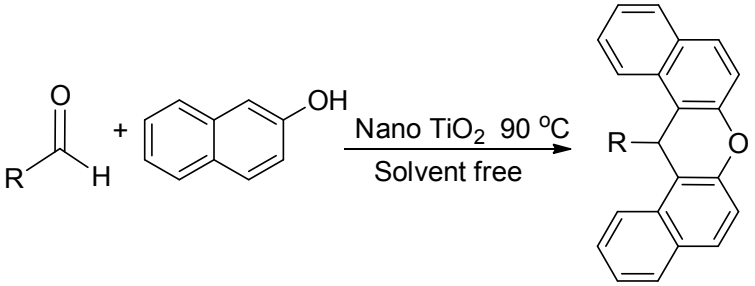
Diethyl acetylenedicarboxylate (1 mmol), 3,4-dimethyl aniline (1 mmol), isopropyl amine (1.2 mmol), propionaldehyde (1.1 mmol), and 5 ml DCM were taken in a 25 ml round bottomed flask. The resulting mixture was then refluxed for the mentioned period of time in the presence of various catalysts.

2.1.10. Synthesis of 14-aryl or alkyl-14H-dibenzo[a,j]xanthenes

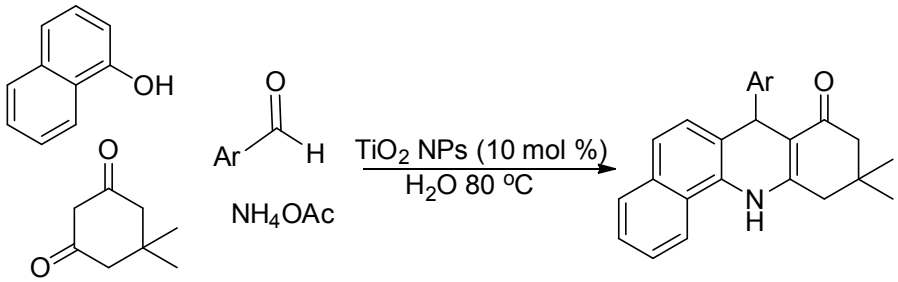
B. F. Mirajalili and *et al.* reported the synthesis of 14-aryl-14H-dibenzo[a,j]xanthene derivatives under heating conditions by reaction between 2-Naphthol and various aldehydes in presence of nano TiO_2. It was observe the protocol is simple method for the synthesis of 14-aryl or alkyl-14H-dibenzo[*a,j*] xanthenes using nano-TiO2 as eco-friendly and efficient catalyst [35].



Scheme 10: Synthesis of 14-aryl or alkyl-14H-dibenzo[a,j]xanthenes

2.2.11 Synthesis of series of tetrahydrobenzo[c]acridinone derivatives

Sharhzad abdolmohammadi *et al.* reported a four component one-pot synthesis of series of tetrahydrobenzo[c]acridinone derivatives in aqueous media using a catalytic amount of titanium dioxide nanoparticles (TiO_2 NPs)**.(Scheme**). The advantages of this novel protocol include the excellent yields, operational simplicity, short reaction time, easy work-up, reusability of the catalyst and an environmentally friendly procedure[36].

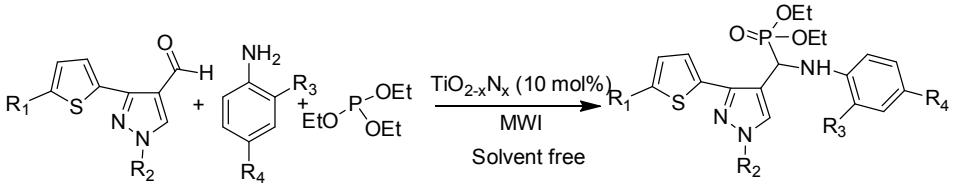


Scheme 11: Synthesis of Tetrahydrobenzo[c]acridines

2.2 Doped TiO_2 as Heterogeneous Catalyst

2.2.1 Kabachnik-Fields reaction Synthesis of α-aminophosphonates

Sachin Kunde *et al.* prepared a series of $TiO_{2-x}N_x$ nanoparticles (NPs) *via* the direct amination method at a relative low temperature [37]. Different proportion of rutile to anatase phases were achieved through simply varying volume ratio of $TiCl_4$, methanol, water and triethylamine. They found the prepared $TiO_{2-x}N_x$ (NPs) showed enhanced catalytic activity than commercial available TiO_2 in Kabachnik-Fields reaction under microwave irradiation (**Scheme 11)**.



Scheme 11: Synthesis of α-aminophosphonates

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III. Conclusion

In this paper we have reviewed the dependence of catalytic activity in organic transformation with structural modification of TiO2 nanoparticles Different modifications of TiO_2 extends the catalyst selectivity and reusability over unmodified TiO_2 nanoparticles. Recent investigations have shown that modified TiO_2 nanostructures utilised as active catalysts or catalyst support in organic transformations including C-C, C-N, C-S, C-O bond formation reactions, multicomponent reactions (MCR), oxidation- reductions.

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References

[1]. Wang, S., Zeng, J., Huang, Y., Shi, C., & Zhan, P. (2018). The effects of urbanization on CO2 emissions in the Pearl River Delta: a comprehensive assessment and panel data analysis. Applied Energy, 228, 1693-1706.

[2]. Tian, H., Gao, J., Hao, J., Lu, L., Zhu, C., & Qiu, P. (2013). Atmospheric pollution problems and control proposals associated with solid waste management in China: a review. Journal of Hazardous Materials, 252, 142-154.

[3]. Boreskov, G. K. (2003). Heterogeneous catalysis. Nova Publishers

[4]. Brennführer, A., Neumann, H., & Beller, M. (2009). Palladium-catalyzed carbonylation reactions of aryl halides and related compounds. Angewandte Chemie International Edition, 48(23), 4114-4133.

[5]. Godino-Ojer, M., Milla-Diez, L., Matos, I., Durán-Valle, C. J., Bernardo, M., Fonseca, I. M., & Pérez Mayoral, E. (2018). Enhanced catalytic properties of carbon supported zirconia and sulfated zirconia for the green synthesis of benzodiazepines. ChemCatChem, 10(22), 5215-5223.

[6]. Kumar, S., & Gupta, V. (2004). Tools for Facilitating Natural Product Research. Novel compounds from natural products in the new millennium: potential and challenges, 40.

[7]. Ahadi, S., Mirzaei, P., & Bazgir, A. (2010). One-Pot, Three-Component Synthesis of 3-(5-Amino-1 H-pyrazol-4-yl)-3-(2-hydroxy-4, 4-dimethyl-6-oxocyclohex-1-enyl) indolin-2-ones. Synthetic Communications®, 40(8), 1224-1230.

[8]. Sheldon, R. A. (2005). Green solvents for sustainable organic synthesis: state of the art. Green Chemistry, 7(5), 267-278.

[9]. Amorós-Pérez, A. (2019). TiO2 based photocatalysts for environmental remediation reactions.

[10]. Kobayashi, S., & Ishitani, H. (1999). Catalytic enantioselective addition to imines. Chemical Reviews, 99, 1069-1094.

[11]. Upadhyay, P., & Srivastava, V. (2016). Proline based organocatalysis: supported and unsupported approach. Current Organocatalysis, 3(3), 243-269.

[12]. Zheng, H., Lin, Y., Wang, M., Liu, J., Wu, D., Chen, J., ... & Zhao, S. (2019). The influence of solvent polarity on the dehydrogenation of isoborneol over a Cu/ZnO/Al2O3 catalyst. Catalysis Today, 323, 44-53.

[13]. Zhang, H., Dai, L., Feng, Y., Xu, Y., Liu, Y., Guo, G., ... & Deng, J. (2020). A Resource utilization method for volatile organic compounds emission from the semiconductor industry: Selective catalytic oxidation of isopropanol to acetone Over Au/α-Fe2O3 nanosheets. Applied Catalysis B: Environmental, 275, 119011.

[14]. Trangwachirachai, K., Chen, C. H., & Lin, Y. C. (2021). Anaerobic conversion of methane to acetonitrile over solid-state-pyrolysis-synthesized GaN catalysts. Molecular Catalysis, 516, 111961.

[15]. Aprile, C., Corma, A., & Garcia, H. (2008). Enhancement of the photocatalytic activity of TiO 2 through spatial structuring and particle size control: from subnanometric to submillimetric length scale. Physical Chemistry Chemical Physics, 10(6), 769-783.

[16]. Suryanarayana, C. C. K. C., & Koch, C. C. (2000). Nanocrystalline materials–Current research and future directions. Hyperfine interactions, 130(1), 5-44.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
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[17]. Ponnamma, D., Cabibihan, J. J., Rajan, M., Pethaiah, S. S., Deshmukh, K., Gogoi, J. P., ... & Cheng, C. (2019). Synthesis, optimization and applications of ZnO/polymer nanocomposites. Materials Science and Engineering: C, 98, 1210-1240.

[18]. Tuller, H. L., & Bishop, S. R. (2011). Point defects in oxides: tailoring materials through defect engineering. Annual Review of Materials Research, 41, 369-398.

[19]. Rao, M. C., & Ravindranadh, K. Insight into Nanotechnology and Applications of Nanomaterials.

[20]. Terna, A. D., Elemike, E. E., Mbonu, J. I., Osafile, O. E., & Ezeani, R. O. (2021). The future of semiconductors nanoparticles: Synthesis, properties and applications. Materials Science and Engineering: B, 272, 115363.

[21]. Terna, A. D., Elemike, E. E., Mbonu, J. I., Osafile, O. E., & Ezeani, R. O. (2021). The future of semiconductors nanoparticles: Synthesis, properties and applications. Materials Science and Engineering: B, 272, 115363.

[22]. Iriarte-Velasco, U., Ayastuy, J. L., Boukha, Z., Bravo, R., & Gutierrez-Ortiz, M. Á. (2018). Transition metals supported on bone-derived hydroxyapatite as potential catalysts for the Water-Gas Shift reaction. Renewable Energy, 115, 641-648.

[23]. Chheda, J. N., & Dumesic, J. A. (2007). An overview of dehydration, aldol-condensation and hydrogenation processes for production of liquid alkanes from biomass-derived carbohydrates. Catalysis Today, 123(1-4), 59-70.

[24]. Gürbüz, E. I., Kunkes, E. L., & Dumesic, J. A. (2010). Dual-bed catalyst system for C–C coupling of biomass-derived oxygenated hydrocarbons to fuel-grade compounds. Green Chemistry, 12(2), 223-227.

[25]. Chheda, J. N., Huber, G. W., & Dumesic, J. A. (2007). Liquid-phase catalytic processing of biomass-derived oxygenated hydrocarbons to fuels and chemicals. Angewandte Chemie International Edition, 46(38), 7164-7183.

[26]. Villas-Boas Hoelz, L., Gonçalves, B. T., Barros, J. C., & Mendes da Silva, J. F. (2010). Solvent free, microwave assisted conversion of aldehydes into nitriles and oximes in the presence of NH2OH• HCl and TiO2. Molecules, 15(1), 94-99.

[27]. Baghbanian, S. M., Farhang, M., & Baharfar, R. (2011). One-pot three-component synthesis of α-amino nitriles catalyzed by nano powder TiO2 P 25. Chinese Chemical Letters, 22(5), 555-558.

[28]. Gawande, M. B., Pandey, R. K., & Jayaram, R. V. (2012). Role of mixed metal oxides in catalysis science—versatile applications in organic synthesis. Catalysis Science & Technology, 2(6), 1113-1125.

[29]. TiO2 NPs as a reusable heterogeneous catalyst for synthesis of spiroxindole-pyrrolidine by reacting of 3-aryl-1-(pyridin-2-yl)-prop-2-en-1-one, isatins and benzylamines via 1,3-dipolar cycloaddition reaction using water as reaction media.30

[30]. Kassaee, M. Z., Mohammadi, R., Masrouri, H., & Movahedi, F. (2011). Nano TiO2 as a heterogeneous catalyst in an efficient one-pot three-component Mannich synthesis of β-aminocarbonyls. Chinese Chemical Letters, 22(10), 1203-1206.

[31]. Shirini, F., Abedini, M., & Seddighi, M. (2016). TiO2 and Its Derivatives as Efficient Catalysts for Organic Reactions. Journal of Nanoscience and Nanotechnology, 16(8), 8208-8227.

[32]. Rana, S., Brown, M., Dutta, A., Bhaumik, A., & Mukhopadhyay, C. (2013). Site-selective multicomponent synthesis of densely substituted 2-oxo dihydropyrroles catalyzed by clean, reusable, and heterogeneous TiO2 nanopowder. Tetrahedron Letters, 54(11), 1371-1379.

[33]. Abdolmohammadi, S. (2018). TiO2 NPs-coated carbone nanotubes as a green and efficient catalyst for the synthesis of [1] benzopyrano [b][1] benzopyranones and xanthenols in water. Combinatorial Chemistry & High Throughput Screening, 21(8), 594-601.

[34]. Abdolmohammadi, S., Mohammadnejad, M., & Shafaei, F. (2013). TiO2 nanoparticles as an efficient catalyst for the one-pot preparation of tetrahydrobenzo [c] acridines in aqueous media. Zeitschrift für Naturforschung B, 68(4), 362-366.

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[35]. Abdolmohammadi, S., Mohammadnejad, M., & Shafaei, F. (2013). TiO2 nanoparticles as an efficient catalyst for the one-pot preparation of tetrahydrobenzo [c] acridines in aqueous media. Zeitschrift für Naturforschung B, 68(4), 362-366.

[36]. Abdolmohammadi, S., Mohammadnejad, M., & Shafaei, F. (2013). TiO2 nanoparticles as an efficient catalyst for the one-pot preparation of tetrahydrobenzo [c] acridines in aqueous media. Zeitschrift für Naturforschung B, 68(4), 362-366.

[37]. Kunde, S. P., Kanade, K. G., Karale, B. K., Akolkar, H. N., Arbuj, S. S., Randhavane, P. V., ... & Kulkarni, A. K. (2020). Nanostructured N doped TiO 2 efficient stable catalyst for Kabachnik–Fields reaction under microwave irradiation. RSC Advances, 10(45), 26997-27005.