



Green Technologies for Sugar Industry: Sustainability for Profitability

SUNIL DHOLE, PHD (CHEM ENGG)

CO-FOUNDER AND DIRECTOR

CHEMDIST



Delivering Separation & Process Technology

Team



Director & Co-Founder

Dr. Sunil Dhole

PhD (Chemical Engineering), IIT Kanpur

Panel Member

- Board of Director at Water Quality India Association
- Committee Member of Bureau of "Indian Standard for Community Water Purifier"



Director & Co-Founder

Tushar Wagh

MBA, Chemical Engineering



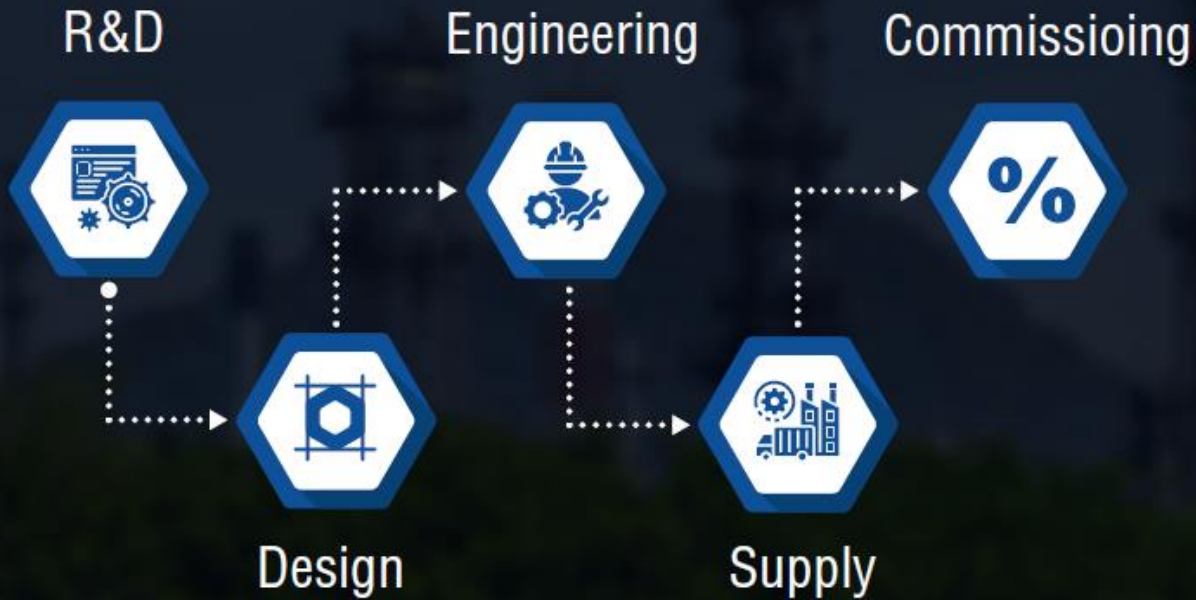
Mentor

Prof. J B Joshi (Padma Bhushan)

- International Member of the National Academy of Engineering of the United States of America
- Emeritus Professor of Eminence, ICT

What We Do

Delivering Separation & Process Technologies



Capabilities

Area of Expertise



Heat & Mass Transfer

- Heat Exchanger
- Mass Transfer Internals
- Turbulator
- Reactors & Agitators

Membrane Technology

- Gas Separation
- Membrane Distillation
- Ultrafiltration-NanoFiltration
- Pervaporation

Process Technologies

- Distillation
- Evaporation
- Reaction & Mixing
- Oil & Gas Technology

Team & Facilities

- 100+ Engineers
- 250+ workers

Commissioned Projects



Infrastructure

- 3 Fabrication Units
- 1 Lakh Sq. Ft. Area



Journey So Far



50+
Successful Turnkey
Projects Installation



500+
Clients Served



12+
Industrial
Segments



10+
Patents



30+
Products



10+
Technologies



6000+
Oxygen Concentrators
Running



6 Mn
Tata Swach Serving
People Per Day



100 Mn
Mask Delivered

Collaborations



Our R&D Network



Dr. Dipankar Bandopadhyay
Professor, IIT Guwahati
(Clean Energy - Fuel and Solar Cells)



Dr. Amol Kulkarni
Scientist, CSIR-National Chemical Laboratory
(Continuous Manufacturing and Scale-up)



Dr. Srinivas Mettu
Senior Research Fellow, RMIT University
(Bio-Technology)



Dr. Akshai Kumar Alape Seetharam
Assistant Professor, IIT Guwahati
Catalysis (Heterogeneous and Homogeneous)



Dr. Nageswara Rao Peela
Associate Professor, IIT Guwahati
(Biomass Conversion to Value Added Chemicals)



Dr. Vivek Vitankar
Ph.D, ICT Mumbai & Director at FluidDimensions
(Computational Fluid Dynamics)



Dr. Sandip Patil
Ph.D, IIT Kanpur & Director, E-Spin Nanotech Pvt. Ltd.
(Nano Technology)



Dr. Uttam Manna
Professor, IIT Guwahati
(Bio-inspired Polymer Materials)

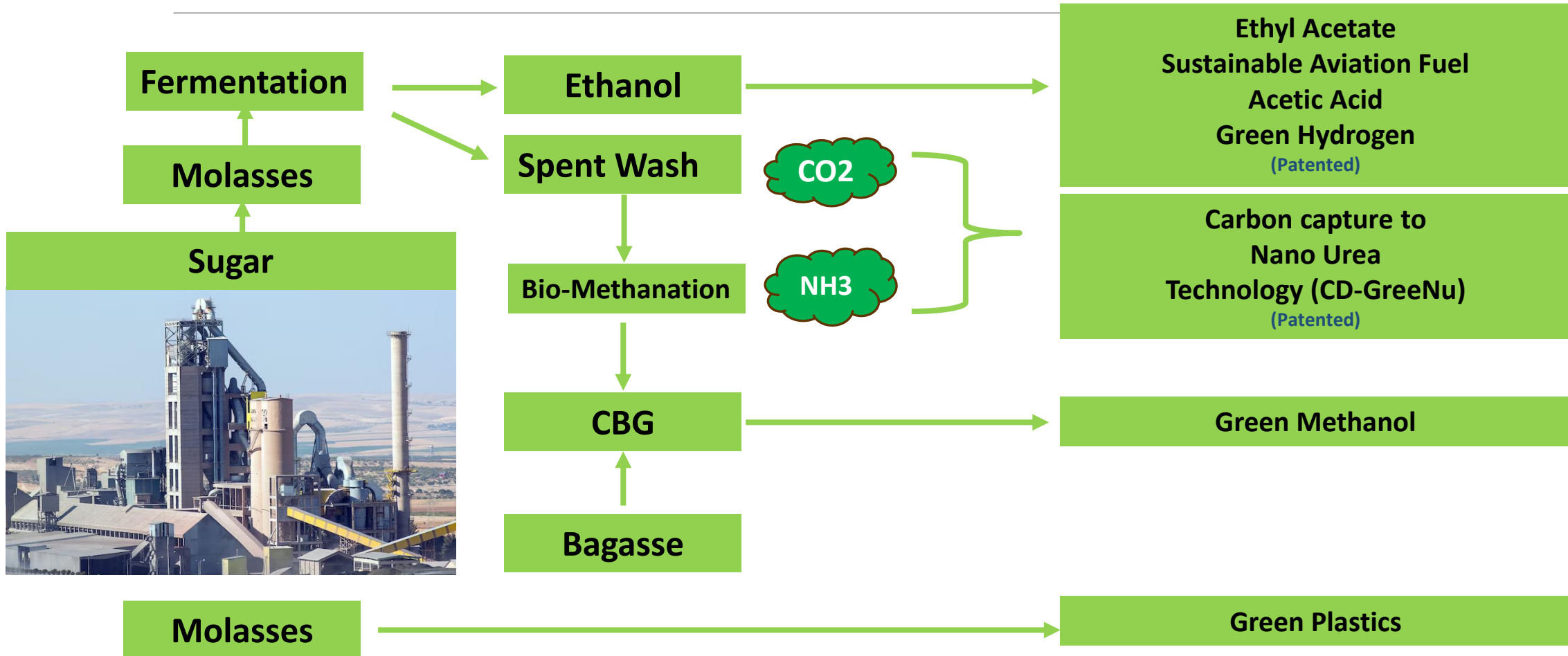


Dr. Tapas K. Mandal
Professor, IIT Guwahati
(Micro-Nano Technology for Energy Harvesting)

Our Focus

- To innovate and scaleup green technologies which are commercially feasible in today's market scenario
- The Net Zero technologies giving green consumable products along with the green Hydrogen as a by product
- Use of Green Hydrogen in the existing chemical industry
- To Convert captured carbon (CO₂) into valuable Agro-products of mass consumption

Why Sugar Industry?



Our Technologies

1. Captured CO₂ and NH₃ (from Sugar Factory) to Nano-Urea
2. Bio-ethanol to Bio-Aviation Fuel (SAF) and Green Hydrogen*
3. Bio-ethanol to Acetic Acid and Green Hydrogen*
4. Bio-ethanol to Ethyl Acetate and Green Hydrogen*
5. Low temperature cracking of Ammonia to Hydrogen and Nitrogen (no emissions of Nox)
6. Methanol cracking to Formic Acid and Hydrogen (with no emissions of CO and CO₂)* (Bagasse)
7. Bio-mass to Green Plastic (no CO₂ emissions in the process)

* Green Hydrogen is a by-product, the commercial feasibility comes from the main product

Nano-Fertilizer Market Driver

Problems with the Existing Fertilizers:

1. Wastage – up to 70%
2. Efficiency – up to 30%
3. Carbon foot print – One of the highest carbon foot print product
4. GHG emissions – Up to 6% of the total emissions
5. Pollution: Water, air and Soil
6. Soil Fertility and Productivity – Reduction due to over use

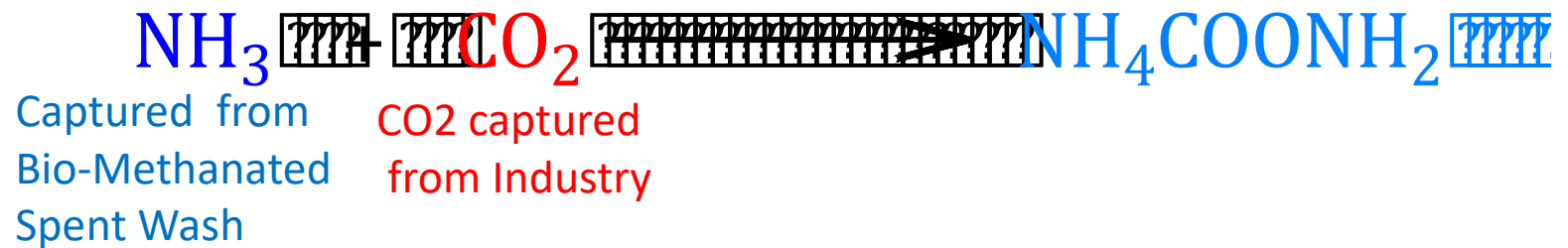
Market Potential

ChemDist – Green Nano-Urea Technology		
Sr. No.	Patented Technologies	Product Market by 2030
1	Waste CO2 to Nano-Urea	Bn 200 USD (nano-fertilizer)

Competitive Advantages

- Bio raw materials (CO₂ and Ammonia captured from Sugar Factory) to produce **Carbon Neutral Nano-Urea**
- Low temperature process
- The catalyst invented by us is based on the abundantly available metals
- Catalyst will be manufactured inhouse to have a complete control on the business chain
- Affordable Nano-Urea

CD Nano - Urea Process



Urea Conversion to Nano-Urea
Using CD-Bind slow release
binder

Nano Urea with 20%-30%
Nitrogen

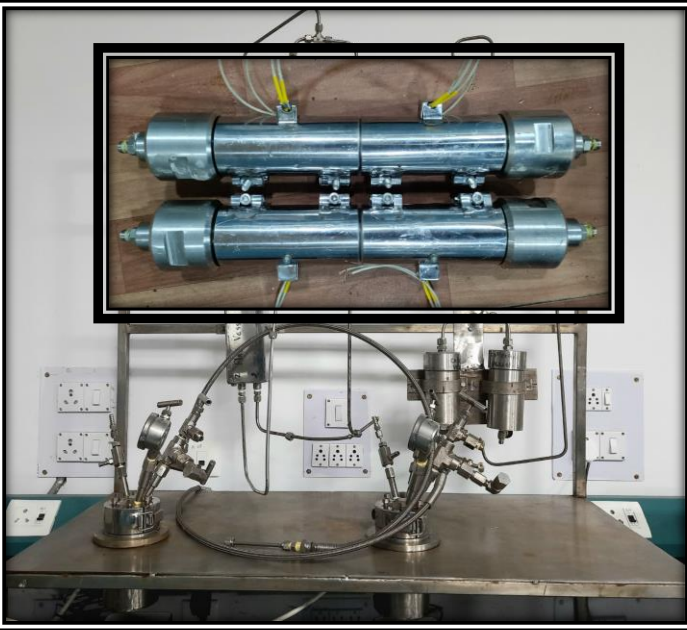
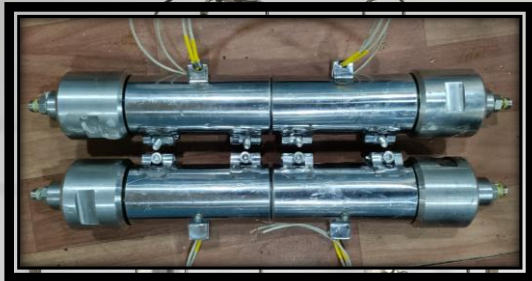
Conventional Urea : Challenges

	Conventional Urea
Environmental Pollution	Soil, Water and Air
CO2 Footprint	Very High
Renewable and Green	No
Nitrogen Convey	30-50 % to plants
Sustain Release	No. Due to which more urea wasted in climate
Available Form	Solid
NOx	NOx formation during use
Soil Yield / Fertility	Continuous use decreases soil yield

Labs



Pilot and Lab Plants



Synthesis of Nano-Urea

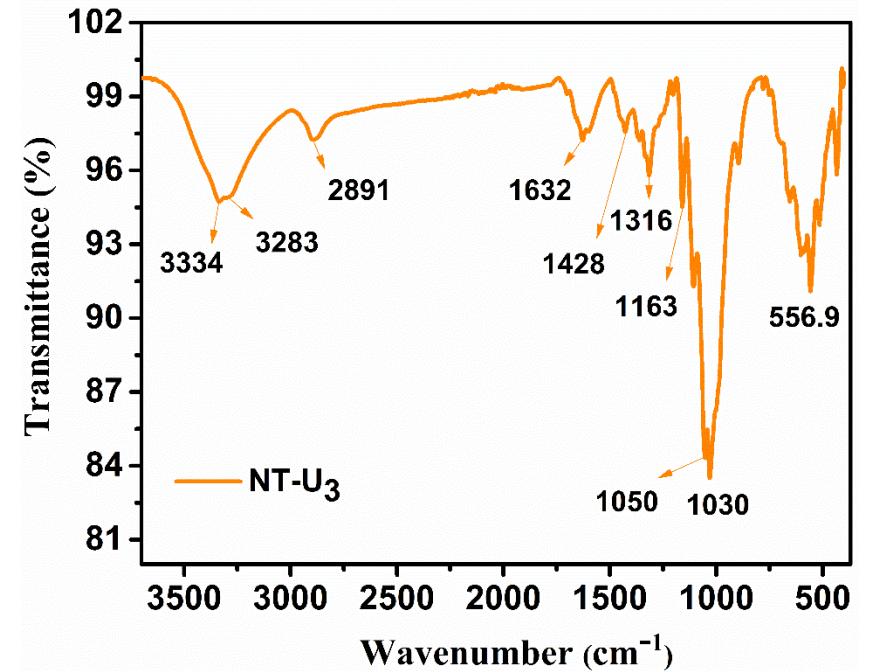
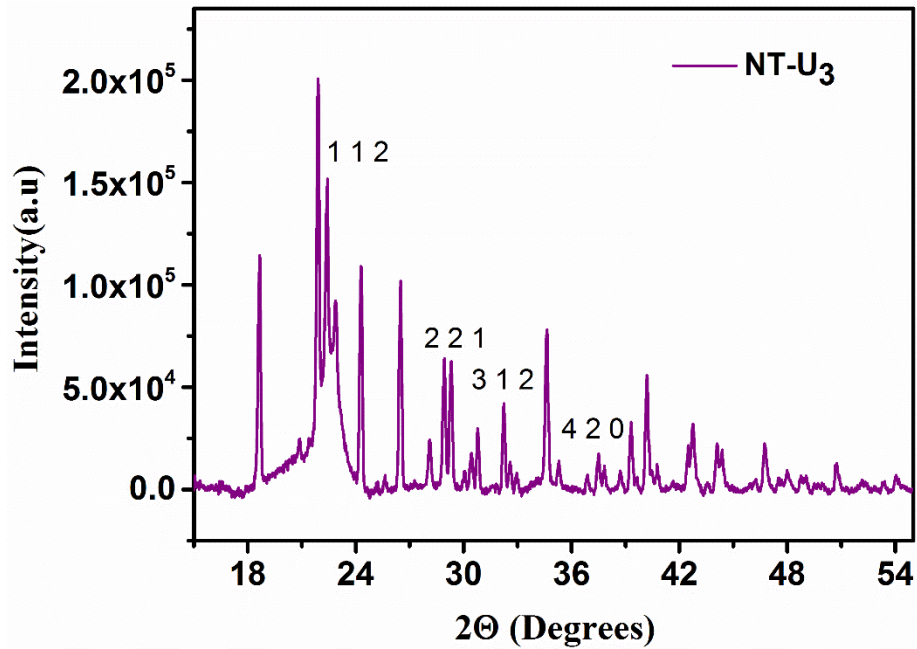
Nitrogen

Weight % = 20-30 %

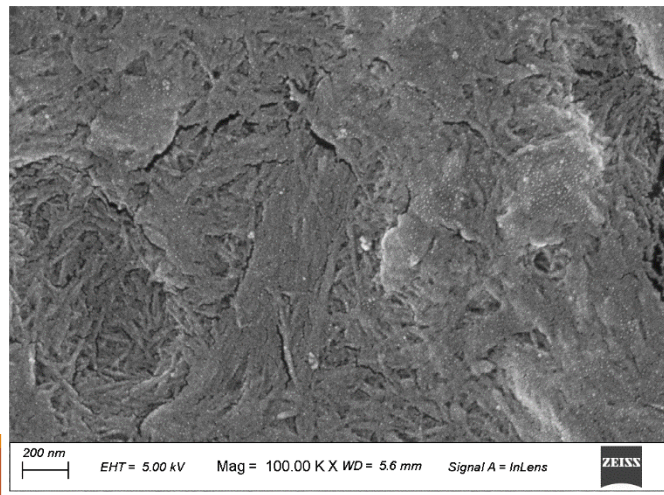
Nano fringes of ~30-40 nm

Highly crystalline material

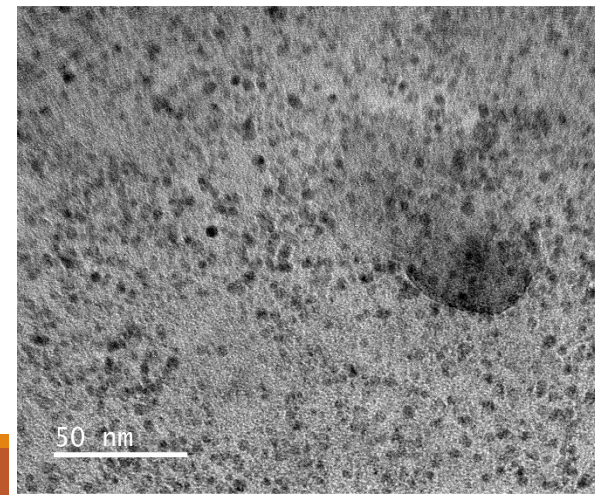
Synthesis of Nano-Urea- Nano Urea : Binder (1:1)



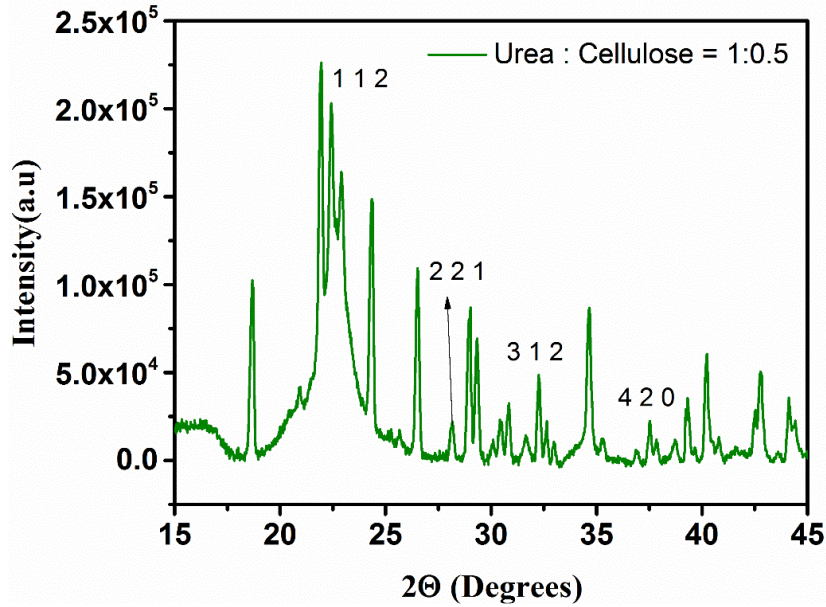
FESEM



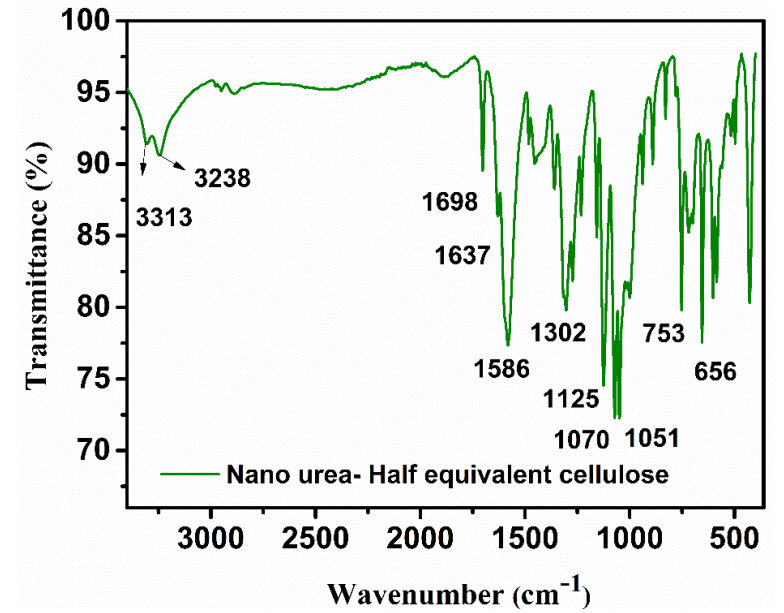
FETEM



Synthesis of Nano-Urea- Nano Urea : Binder (1:0.5)

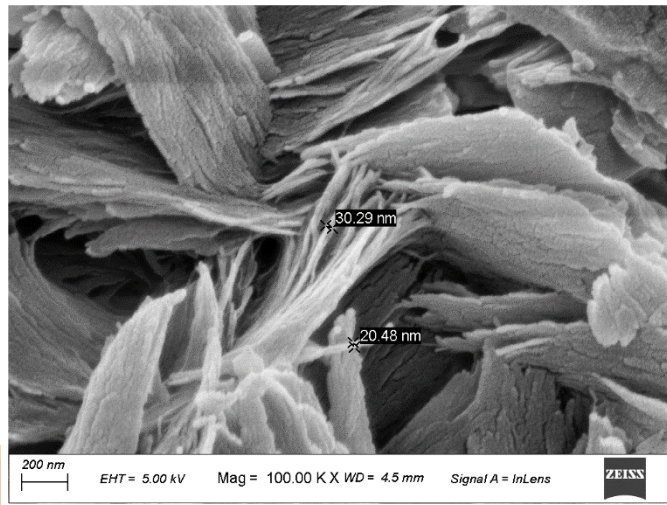


p-XRD

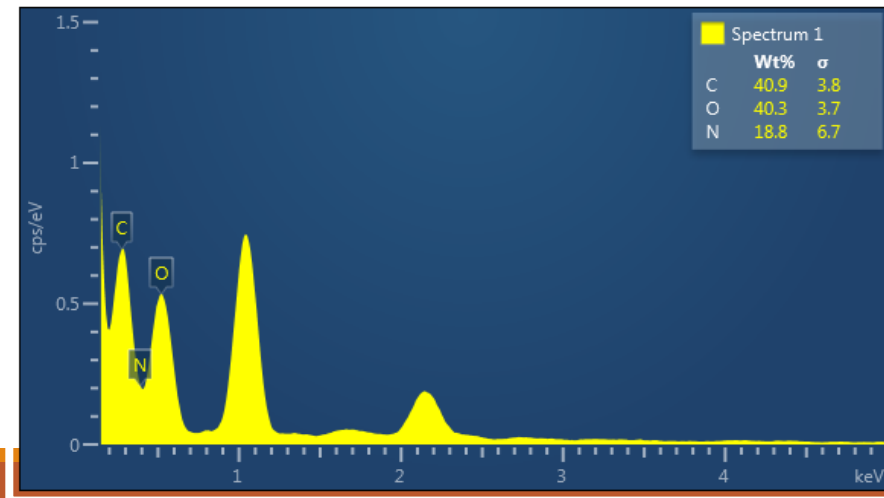


FTIR

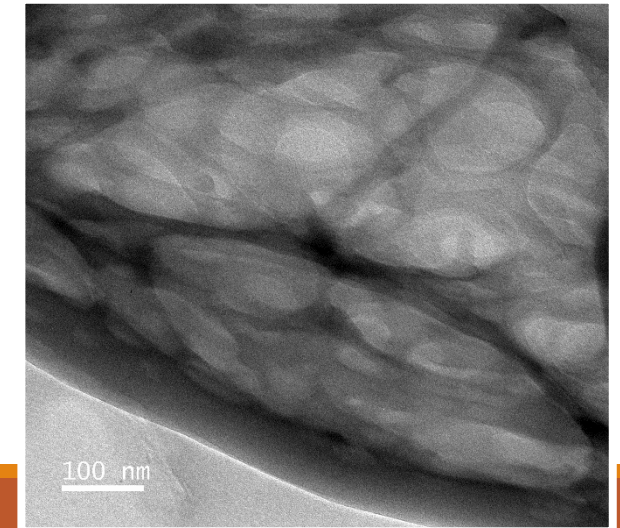
FESEM



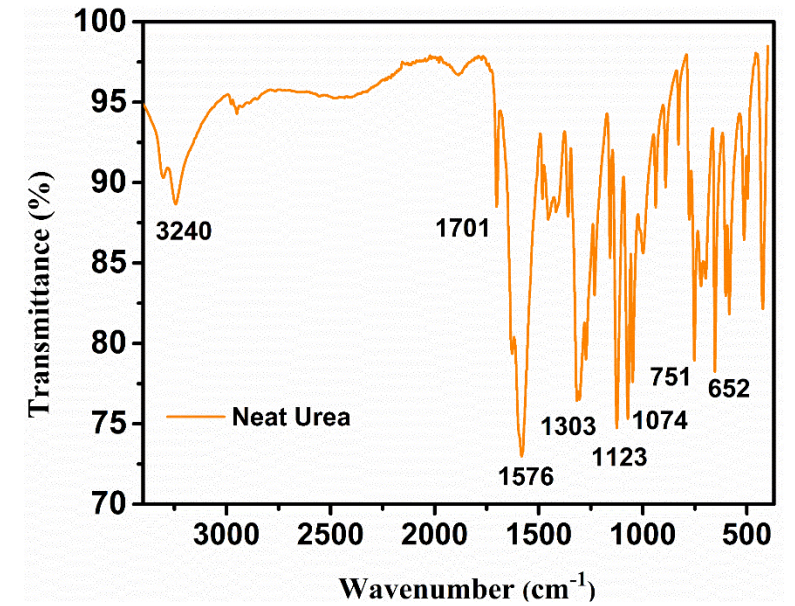
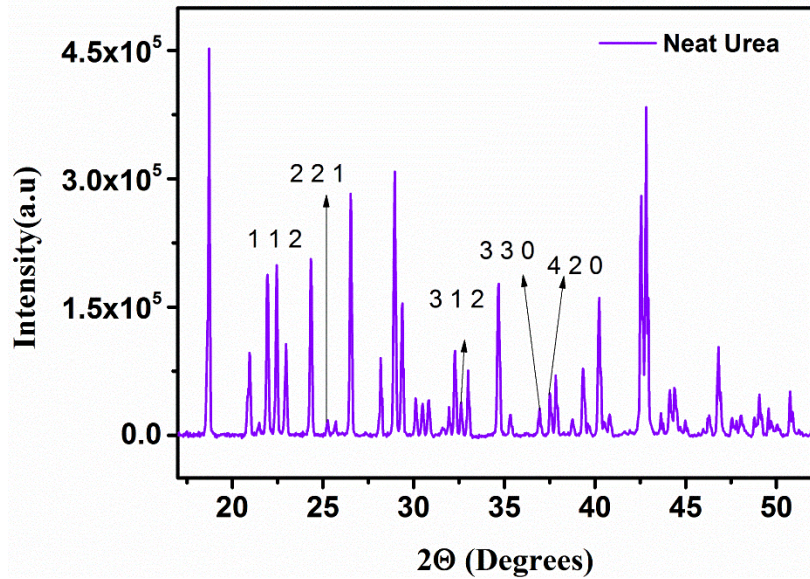
EDS



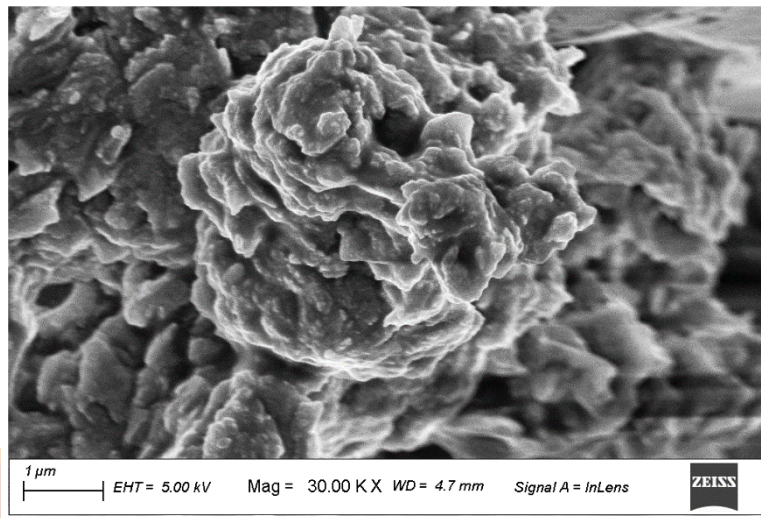
FETEM



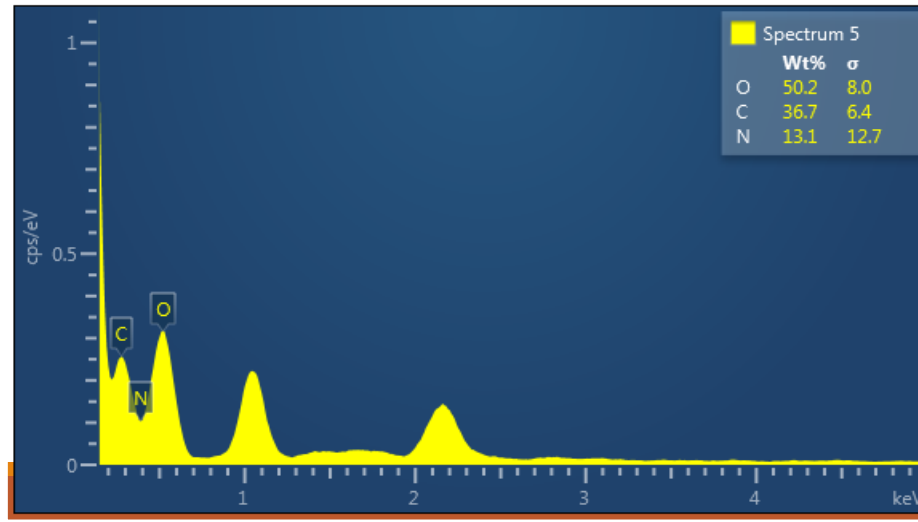
Synthesis of Nano-Urea- Nano Urea (100%)



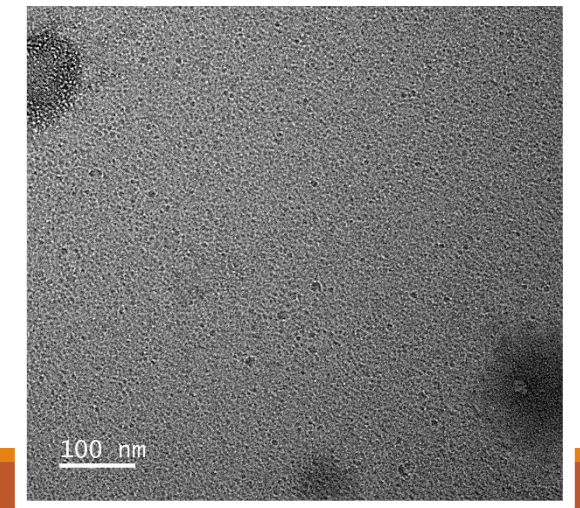
FESEM



EDS



FETEM



Synthesis of Nano-Urea- Characterizations

Sample	p-XRD	FESEM	EDS	FETEM	FTIR	NMR		Zeta potential
						¹ H	¹³ C	
100% Nano Urea	✓	✓	✓	✓	✓	✓	✓	✓
Nano Urea: Slow release Binder 1:0.5 equivalent	✓	✓	✓	✓	✓	✓	✓	✓
Urea: Slow release Binder 1:1 equivalent	✓	✓	✓	✓	✓	✓	✓	✓

Nitrogen Content – 20-23%

Soyabean Crop Trials (MPKV Rahuri)

T1	Control
T2	Recommended dose of Fertilizers
T3	Recommended dose of Biochar (N% =)
T4	20% Less of RDF of Biochar
T5	20% More of RDF Biochar
T6	Recommended Dose of Nanourea (N%=)
T7	20% Less of RDF Nano urea
T8	20% More of RDF Nanourea
T9	Biochar + Nanourea
T10	20% less of BN Content
T11	20% More of BN Content
T12	Rhizobium + Biochar
T13	Azotobactor + Biochar
T14	FVM + Biochar
T15	FVM + Biochar
	Total Nano Urea required (kgs)
	Biochar (Kgs)
Plot Size	3 x 3 m
Design	Randomize Block Design
Total Area Required	125 sqm / replication
Replications	3

CD - Nano Urea : Field Trials

(MPKV Rahuri)



Conventional Urea Vs. Nano Urea

	Conventional Urea	ChemDist Nano Urea Technology
Environmental Pollution	Soil, Water and Air	Nil Pollution
CO2 Footprint	Very High	Almost NIL
Renewable and Green	No	Yes
Nitrogen Convey	30-50 % to plants	More than 80 % to Plant
Sustain Release	No. Due to which more urea wasted in climate	Yes. Due to which no wastage of Nano Urea in climate.
Available Form	Solid	Solid
NOx	NOx formation during use	No NOx emissions
Soil Yield / Fertility	Continuous use decreases soil yield	Increased soil yield and increase in crop production

Media Coverage



BBC coverage on Oxygen Concentrators



Ministry of Education tweets about CD-OXY



PM. Narendra Modi wears our N95 SWASA Mask



Our R&D Network



Dr. Dipankar Bandopadhyay
Professor, IIT Guwahati
(Clean Energy - Fuel and Solar Cells)



Dr. Amol Kulkarni
Scientist, CSIR-National Chemical Laboratory
(Continuous Manufacturing and Scale-up)



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Ph.D, IIT Kanpur & Director, E-Spin Nanotech Pvt. Ltd.
(Nano Technology)



Dr. Uttam Manna
Professor, IIT Guwahati
(Bio-inspired Polymer Materials)



Dr. Tapas K. Mandal
Professor, IIT Guwahati
(Micro-Nano Technology for Energy Harvesting)



ChemDistGroup of Companies is the industry collaborator on this project. Speaking on the industrial potential of the research Dr. Sunil Dhole, Director, ChemDist Group of Companies, said, "Commercially speaking, the exciting fact about this work is that an abundantly available and cheaper organic chemical like Methanol can be converted to Hydrogen using a cheaper catalyst, at lower temperatures and without the emission of Carbon Dioxide. This technology has the potential to make significant strides towards achieving carbon neutrality."

The details of the catalytic system have been published in ACS Catalysis. The paper has been co-authored by Vinay Arora, Eileen Yasmin, Niharika Tanwar, Venkatesha R. Hathwar, Tushar Wagh, Sunil Dhole, and Akshai Kumar A.S.

indiatodayne.in

Media Coverage

Selected in Hydrogen Mission by Govt. of India

IITGu Chemdist News covered by 91 Newspapers all over India

<https://www.indiatodayne.in/assam/story/iit-guwahati-researchers-develop-catalyst-to-produce-sustainable-green-hydrogen-fuel-551320-2023-05-01>

ChemDist Media Review

IIT Guwahati Researchers develop catalyst to produce Sustainable Green Hydrogen fuel

Catalysis

Pincer-Ruthenium-Catalyzed Reforming of Methanol—Selective High-Yield Production of Formic Acid and Hydrogen

Vinay Arora, Eileen Yasmin, Niharika Tanwar, Venkatesha R. Hathwar, Tushar Wagh, Sunil Dhole, and Akshai Kumar*

On The ACS Catal. 2023, 13, 1845–1857

ACCESS |

ABSTRACT: A series of NNN pincer-ruthenium complexes of the type $(^{\text{NNN}}\text{RuCl}_2)(\text{CH}_3\text{CO})$ based on $\text{hc}(\text{imino})\text{pyridine}$ ligands were synthesized and characterized. These pincer-ruthenium acetate complexes, along with their phosphine and carbene counterparts, were tested for the reforming of methanol in water in the presence of a base. The catalyst $(^{\text{NNN}}\text{RuCl}_2\text{PPPh}_3)$ was found to be the most efficient in comparison to other considered catalysts. Among the bases screened, K_2CO_3 (1.5 equiv with respect to water) was found to give the best results at temperatures as low as 100°C . Under these conditions, while $(^{\text{NNN}}\text{RuCl}_2\text{PPPh}_3)$ (0.1 mol %) in a mixture of methanol and water as a 1:1 ratio gave a yield of up to 61% each of hydrogen and formic acid (FA) at 80% selectivity, the corresponding reaction with 2 mol % $(^{\text{NNN}}\text{RuCl}_2\text{PPPh}_3)$ gave up to 80% of hydrogen and 75% of FA at 80% selectivity. On the other hand, the $(^{\text{NNN}}\text{RuCl}_2\text{PPPh}_3)$ (0.1 mol %) catalyzed reforming of a 1:1 methanol/water mixture gave good yields (50% of hydrogen with 75% FA at 95% selectivity). The yield of hydrogen was corroborated by using it to reduce unsaturated compounds and determining the corresponding yield of the reduced product, which was found to be consistent. Isotope labeling studies suggest the transformation of C–O–H activation as a part of the catalytic cycle and not as a part of the rate-determining step (RDS) with an average turnover frequency (TOF) of 1.9M. The reaction was observed to have a first-order dependence of rate on the concentration of both $(^{\text{NNN}}\text{RuCl}_2\text{PPPh}_3)$ and methanol. DFT studies are in agreement with this, and the σ -bond metathesis leading to the elimination of the first molecule of hydrogen is compared to be the RDS either for the cycle leading to FA and 2 molar of hydrogen or for the cycle that results in carbon dioxide and 1 molar of hydrogen. The Ru–H species $(^{\text{NNN}}\text{RuH}(\text{CO}))$ plays a decisive role in the subsequent selectivity toward FA. It is in a choice to undergo a σ -bond metathesis either with the C–O–H of methanol (that completes the FA cycle) or with the C–H of FA that leads to carbon dioxide. It shows the former as it is kinetically more favored by a 6.6 kcal/mol. The current catalytic system comprising of NNN pincer-ruthenium phosphines based on $\text{hc}(\text{imino})\text{pyridine}$ ligands that give high yields of FA, and FA at unprecedented selectivity at low operating temperatures offers immense promise in the transformation of methanol to clean-burning hydrogen and high-value FA.

KEYWORDS: pincer-ruthenium complex, dehydrogenation, hydrogen, formic acid, methanol and DFT study

INTRODUCTION

Due to the ever increasing global energy demand and the rapid rate at which fossil fuel reserves are being depleted, there is a great need for the emergence of alternative and clean sources of energy which are sustainable and also would lessen the burden of global pollution. Alternative energy sources explored till date, like solar, wind, tidal, nuclear and geothermal, suffer from several limitations.¹ Thus, a realistic alternative would be utilizing a combination of renewable energy source and fossil fuels, leading to an uninterrupted production and storage of energy.^{2–4} Several reports have emerged over the last few years on the production of H₂ as a clean-burning sustainable energy source with high energy content (120 MJ/kg).^{5–7} Globally, the current emphasis is on sustainable hydrogen production from biomass^{8,9} or via thermochemical, photochemical, or electrolytic splitting of water^{10–12} using electricity from wind^{13,14} solar¹⁵ and geothermal energy.^{16–18} The significant advancement in green hydrogen production is to a large extent overshadowed by the limitations associated with its storage and transportation, which include but are not limited to low volumetric energy

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Selected in Hydrogen Mission by Govt. of India



*With Prof. Ajay Sood (Principal Scientific Advisor to the Prime Minister),
Dr. Raghunath Mhaselkar (Former DG CSIR)*



*With Prof. Abhay Karandikar (Secretary Department of Science
and Technology, Govt. of India), Dr. Ashish Lele (Director CSIR-
NCL)*

A scenic mountain landscape with a hiker on a dirt path. The background features rugged, rocky mountains with patches of green grass and snow. A hiker with a backpack is walking away on a dirt path in the foreground. A small waterfall is visible on the left side of the image.

Thank You

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