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INDIAN INSTITUTE OF TECHNOLOGY
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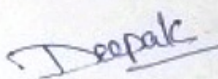
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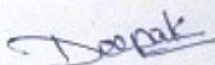
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Acknowledgement

First of all, I bow with reverence and gratitude to thank the Almighty who has enriched me with such an excellent opportunity and infused the power in my mind to fulfill the work assigned to me.

Accomplishment of this doctoral dissertation was possible with the support of several people and I would like to express my sincere gratitude to all of them.

I would like to bow my head to Baba Vishwanath. My deep sense of gratitude to my Guru ji Prof. Ram Prasad, Department of Chemical Engineering & Technology, Indian Institute of Technology (Banaras Hindu University), Varanasi, for his valuable guidance, constant support, critical motivating comments and consistent encouragement that I received throughout the completion of my research work. It is my pleasure to express my deepest admiration and heartiest thanks to him for his harmonious and positive disposition to identify the problem, clarify my doubts and develop an interest for further research in this area. I consider it as a great opportunity to do my doctoral programme under his guidance, to learn from his research expertise that groomed my overall personality. I do not have enough words to describe my gratitude towards him for teaching me how to not only be a better researcher but also a better person. I earnestly owe him for what I am today and what I will be in days to come.

I would like to thank Prof. P.K. Mishra (Head), Department of Chemical Engineering & Technology, Institute of Technology (Banaras Hindu University) and Prof. A. S.K. Sinha, Ex-head of the Department for providing me all the facilities to carry out my research work.

I would also like to express my sincere thanks to RPEC member's Prof. D. Mohan as an external expert from Department of Civil engineering, who continuously

advised, extended academic support and inspired me during RPEC evaluations. I am also thankful to my internal subject expert Prof. P. Ahuja for his valuable remarks and knowledgeable suggestions. I would also like to express my earnest gratitude to Prof. V. L. Yadav (DPGC convener) for her valuable suggestions and affectionate attitude.

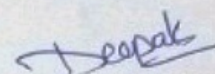
With a special thanks to my seniors Ms. Pratchi Singh and Dr. Ashutosh Kumar, for their help, suggestions and healthy discussions on the research issues. The advices of Dr. Ashutosh in both research and crucial decisions have been priceless. Friendship and funny moments enjoyed with Mr. Abhay Sharma, Mr. Mahendra Ram, Mr. Tarun Dixit, Dr. Praveen Kumar, Mr. Durgesh Kumar and Mr. Ankit Sharma support co-operation and sincere help during my challenging time. I am also thankful to my colleagues and juniors Mr. Subhasish Dey, Ms. Suverna Trivedi, and Mr. Ganesh Dhal, Mr. Ashish R. Kavaiya, for their healthy discussion, support and suggestions during my research work. I am very grateful to our lab assistant Mr. Lal Bhadur for his assistance and frequent support provided during my whole research work. I am also thankful to all office staff of the department and authorities of IIT (BHU), for their kind help during the period of my stay to complete the thesis work.

The dream of my father Late Sh. Sukhbir Singh to complete doctorate and join education field has now come true. Constant inspiration from my mother Smt. Shakuntla Devi with her keen interest to know what I was doing and how to tackle problem in pursuing spiritual path. I am grateful to my elder brother Late Sh. Sandeep Yadav, who have been an emotional support in my life. Words cannot express my gratitude to my soul mate Mrs. Monika Yadav and my lovely kid Shubham who have sacrificed a lot. I am blessed with their care and unconditional support with no expectations.

I want to express my sincere thanks to Mr. Arjun and Mr. Umesh for helping me in characterization of catalyst samples. I also extend my thanks to CIFC, IIT (BHU), Varanasi for the help in characterization of the catalysts.

Last but not the least, everyone who ever impact my performance during my doctoral tenure by their appreciation and critics has been welcomed.

Date 30.06.2018



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List of Notations and Abbreviations

A	Pre-exponential factor (in Arrhenius equation) or frequency factor
C	Concentration
R	Universal gas constant
r	Rate of reaction per unit mass of the catalyst
r_{obs}	Observed rate of reaction per unit mass of the catalyst
T	Absolute temperature
V_m	Volume of the gas required to form a monolayer on a unit gram of sample
W	Weight of the catalyst
F_{NO}	Molar feed rate of NO
X	Fractional conversion
λ	X-ray wavelength in XRD characterization
λ	Air-fuel equivalence ratio
FWHM	Full width half maximum
θ	Bragg's angle
BS	Bharat Stage
Cat	Catalyst
nm	Nano meter
d	Mean crystallite diameter
E	Activation energy
k	Rate constant
n	Order of reaction
P	Gas pressure

g	Gram
GHSV	Gas hourly space velocity
HDV	Heavy Duty Vehicles
hr	Hour
IUPAC	International Union of Pure and Applied Chemistry
mol	Mole
ppm	Parts per million
HC	Hydrocarbon
LDV	Light Duty Vehicles
NMHC	Non methane hydrocarbon
NO _x	Nitrogen oxides
NO	Nitric Oxide
N ₂ O	Nitrous Oxide
OH·	Hydroxy radical
PGM	Platinum group metal
PM	Particulate matter/ Soot
CI	Compression ignition
SI	Spark ignition
IC	Internal combustion

AFR
ARA
atm
BET
BJH
CP
DCP
WI
NC
KIT
DP
ICP
SG
HT
IE
CG
BM
IM
XR
XP
SE
ED
FT
RC
RG
SS

AFR	Air to Fuel ratio
ARAI	Automotive Research Association of India
atm	Atmosphere
BET	Brunauer Emmett and Teller
BJH	Barrett-Joyner-Halenda
CP	Co-Precipitation
DCP	Deposition co-precipitation
WI	<u>Wet Impregnation</u>
NC	Nano Casting
KIT	Korean Institute of Technology
DP	Deposition Precipitation
ICP	Incipient Co-Precipitation
SG	Sol-Gel
HT	Hydrothermal
IE	Ion-Exchange
CG	<u>Co-gelation</u>
BM	Ball-milling
IM	Impregnation
XRD	X-ray Diffraction
XPS	X-ray Photoelectron Spectroscopy
SEM	Scanning electron microscope
EDX	Energy dispersive X-ray spectroscopy
FTIR	Fourier transform infrared spectroscopy
RC	Reactive calcination
RG	Reactive grinding
SSA	Specific surface area

PREFACE

Diesel lean-burn engines conquered increasing concern of greenhouse gas (GHG) emissions and fuel economy over conventional gasoline stoichiometric (A/F=14.7) engines. Lean-burn engines operate under (excess oxygen) conditions of A/F ratio ~ 20-25. A good economy based approach that saves 30-35% fuel consumption and low carbon emission are the main motive for their notable recognition and applications in various fields like transportation, agriculture, defence, power generation, mining, construction, etc. However, emissions of nitrogen oxides (NO_x) and particulate matter (PM) are the main issues from such engines. These pollutants have drastic impact on human health, environment, vegetation, global warming and climate change. To meet the stringent legislations, control of the PM and NO_x emissions are essential. Two separate units, diesel particulate filter (DPF) and selective catalytic reduction (SCR) of NO_x are mandatory for total control of emissions. The PM can be controlled by DPF with an appreciably high reduction (~99%) efficiency. Diesel engines contribute ~58% of the total NO_x emissions. The SCR is one of the best technologies which requires an efficient catalyst and suitable reductant for its effective performance. Hence, reducing NO_x is more complicated than PM elimination from the exhaust. Therefore, the prime objective of the present work was to develop an efficient catalyst and select a suitable reductant for vehicular NO_x emission control.

NO_x are a primary pollutant, typically contain ~95%NO, ~4.5%NO₂ and ~0.5%N₂O. NO_x are the precursor for photochemical formation of more toxic secondary pollutants in the atmosphere such as PAN, PAH, ground level ozone, smog, etc. Alarmed by the adverse impacts of NO_x emissions, Government agencies have enforced stringent legislations which are becoming stricter day by day. The SCR technology is the most appropriate mature technology with high NO_x removal efficiency for diesel and lean burn engines. The main challenge is to find a catalyst system that is active at low temperature, where there is no conversion of NO_x occurs due to low activity at low temperature.

The SCR tests were performed in a fixed-bed glass tubular reactor under the following operating conditions: 200 mg catalyst, 500 ppm NO, 0.1% NH₃/ 1000 ppm C₃H₈ or LPG/1% H₂-1000 ppm C₃H₈, 8% O₂ in Ar, total flow rate of 100 mL/min and temperature ambient to 450°C. The inlet and outlet gases of the reactor were analysed by Eco Physics CLD 62 chemiluminescence NO/NO_x analyzer and online GC. Two

separate GCs equipped with porapak Q/ capillary columns and FID/TCD/ECD detectors were used to analyse the CO, CO₂, hydrocarbons/H₂, N₂O respectively.

The outline of the thesis is as follows:

Chapter 1 includes introduction of the work briefly along with literature review. The outcome of literature survey complies the objectives of the present research work.

Chapter 2 comprises the experimental part which includes catalyst preparation, experimental set up and catalyst characterization (XRD, XPS, SEM, EDX, FTIR, and BET) in details.

Chapter 3 shows catalyst characterization results from XRD, XPS, FTIR, SEM-EDX and BET surface area.

Chapter 4 shows the results and discussion for the choice of catalyst preparation methods, selection of calcination strategies of catalyst precursors, optimization of catalyst loading on support (γ -Al₂O₃) and optimization of promoter (Rh) for NO reduction in the temperature range of ambient to 450°C.

Chapter 5 reports the kinetics study of NO reduction using H₂-C₃H₈ over the best catalyst.

Chapter 6 states the conclusions based on the experimental results and future scope of the present research work.