A Comparative study of Al-Al_2O_3 Micro- and Nano-composites Prepared by Powder Metallurgy Route

K. Dash, D. Chaira!, B. C. Ray

Department of Metallurgical & Materials Engineering, National Institute of Technology Rourkela 769008, India

INTRODUCTION

- Aluminum is a potent material for aerospace as well as automobile applications because it possesses high specific strength, high toughness and corrosion resistance. The mechanical properties of aluminum can be improved by adding ceramic reinforcements to the aluminum matrix.
- The conventional methods of sintering render coarse microstructure, poor adhesion and density, low strength and hardness at high temperatures. The spark plasma sintering technique is becoming popular due to the intrinsic advantages of the method and the enhanced material properties, as well as lower processing temperature and shorter sintering time to consolidate powders compared to conventional methods.
- In this work, we report fabrication of Al-Al_2O_3 metal matrix micro and nano-composites by spark plasma sintering (SPS) technique and compare microstructure evolution , density, hardness and wear studies of both.

Flow Chart for Composite Preparation

Blending of as-received powders Al (micron) and Al_2O_3 powder (micron and nano)

Nano alumina (avg. size< 50 nm): 0.5, 1, 3, 5 & 7 vol. %

Micron alumina (avg. size ~ 10 µm): 1, 5 & 20 vol. %

↓

Spark plasma sintering (SPS)

700°C, 5 minutes, vacuum

↓

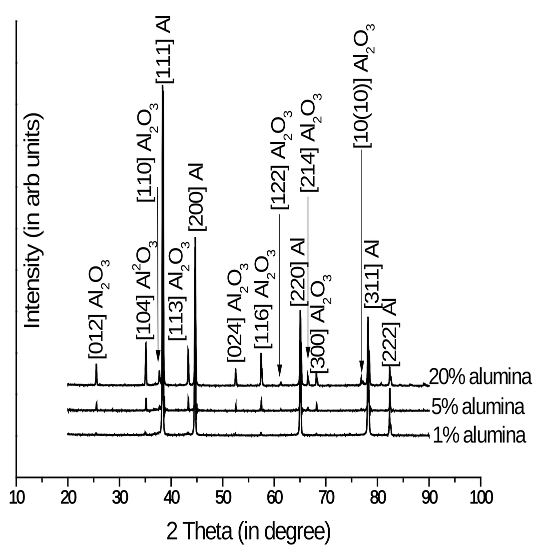
Characterizations by XRD, SEM and TEM

↓

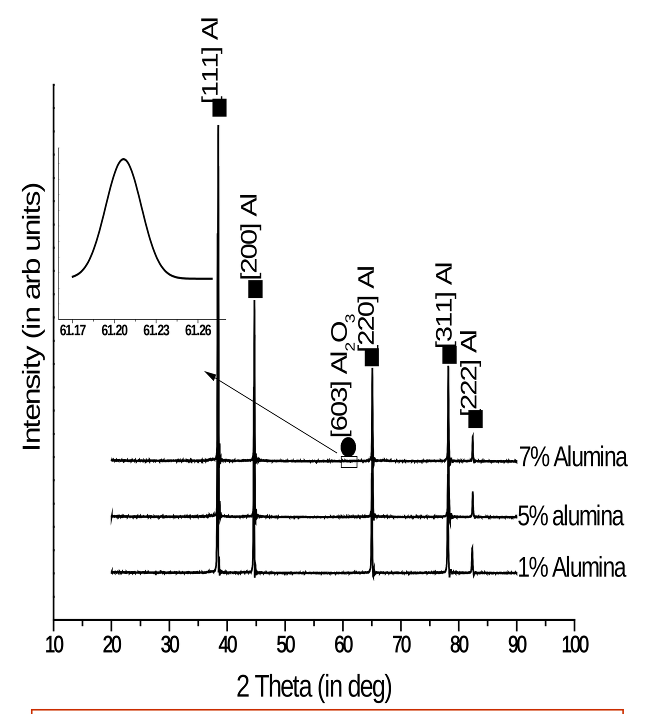
Physical & Mechanical property Study

Density and Hardness, Wear measurement

X-ray Diffraction



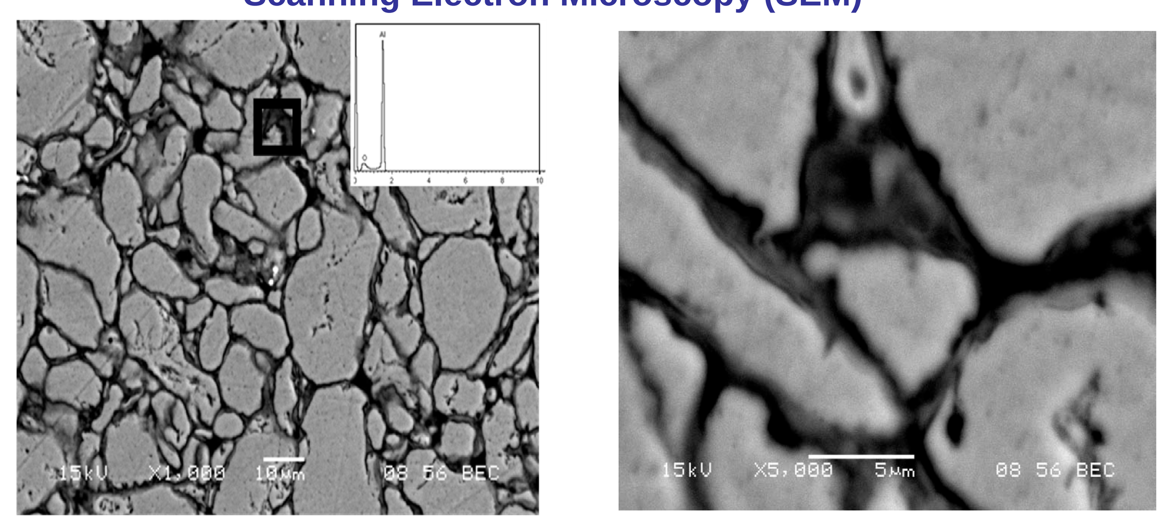
XRD spectra of micro-composites



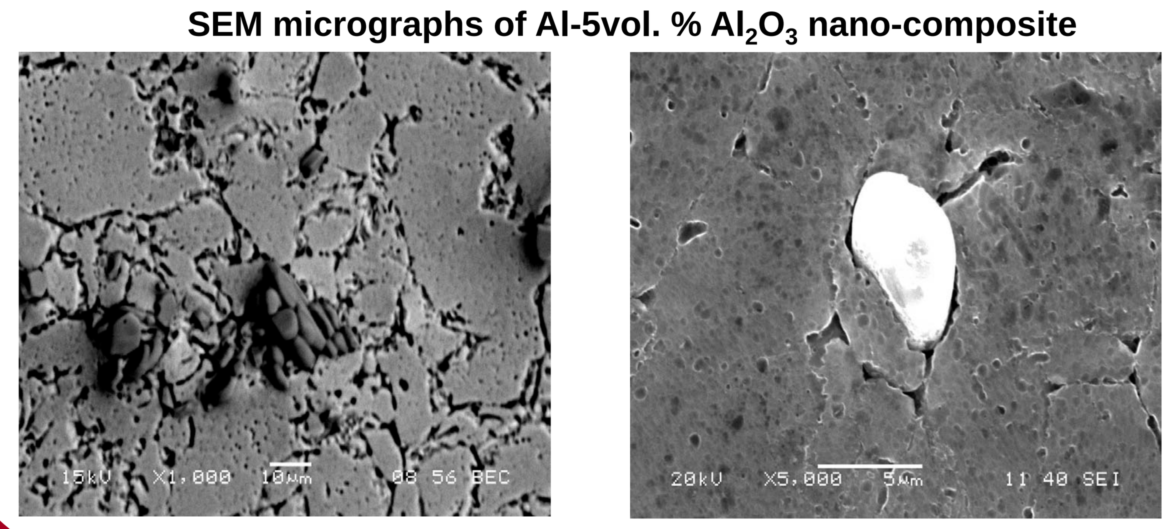
XRD spectra of nano-composites

- Beside Al and Al_2O_3 peaks, no other peak is present after SPS.
- Strong Al_2O_3 peaks are present in case of micro-composite than nano-composite for the same composition.

Scanning Electron Microscopy (SEM)

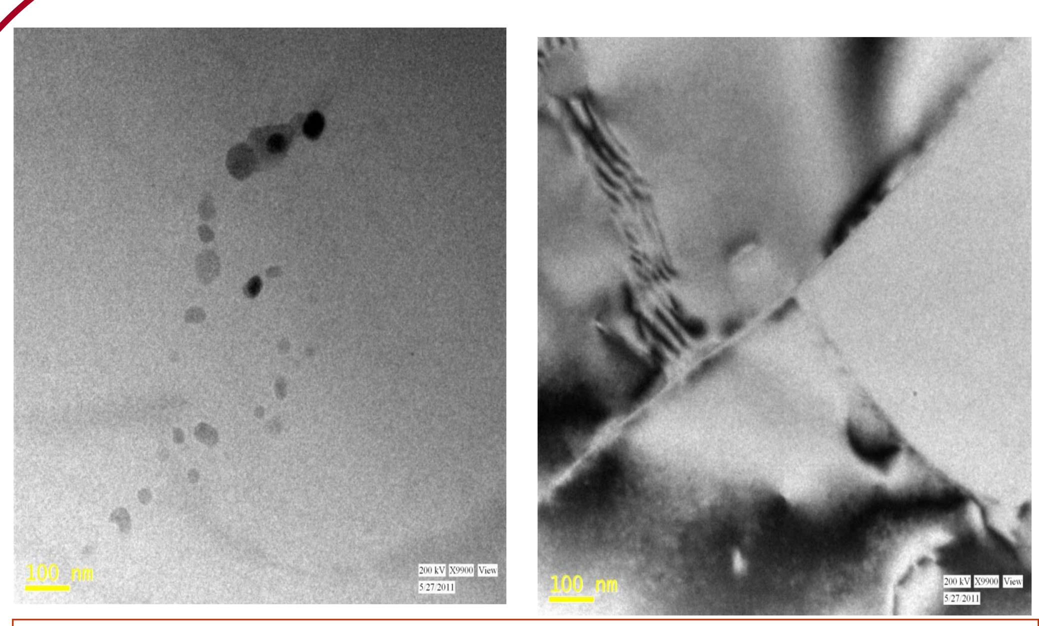


SEM micrographs of Al-5vol. % Al_2O_3 nano-composite



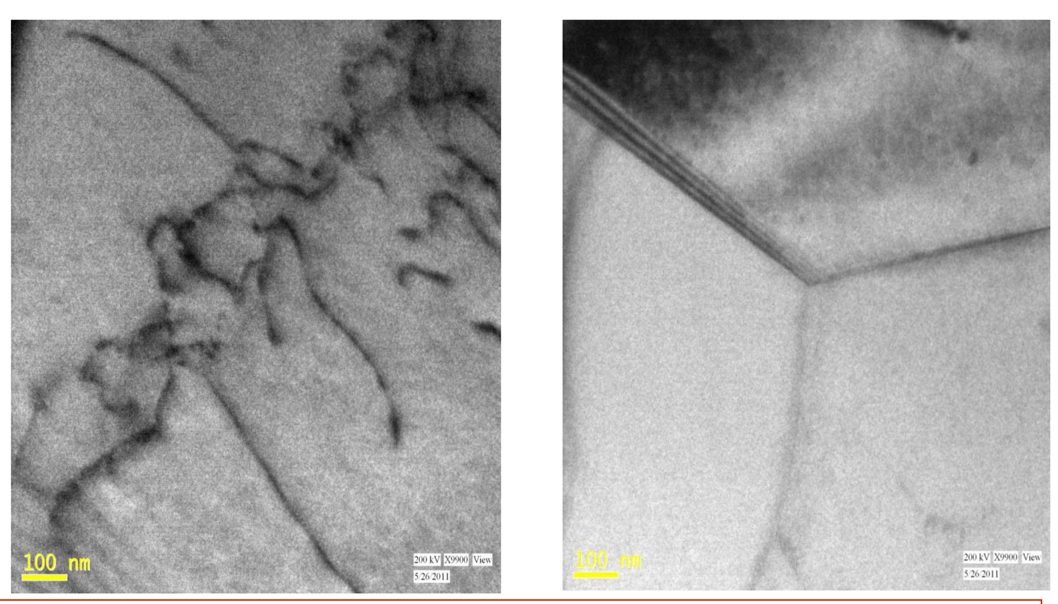
SEM micrographs of Al-5vol. % Al_2O_3 micro-composite

Transmission Electron Microscopy (TEM)



- Al_2O_3 nanoparticles of size around 50 nm are distributed into Al matrix
- Large number of dislocations are pinned and piled up at Al/alumina interface

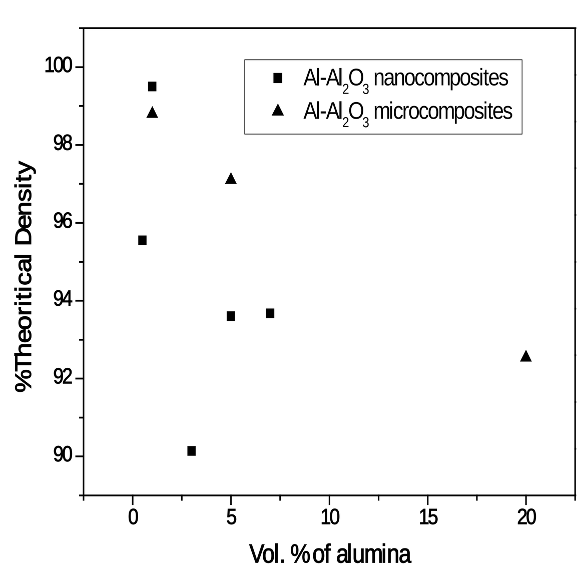
Al-7 vol. % Al_2O_3 nano-composite

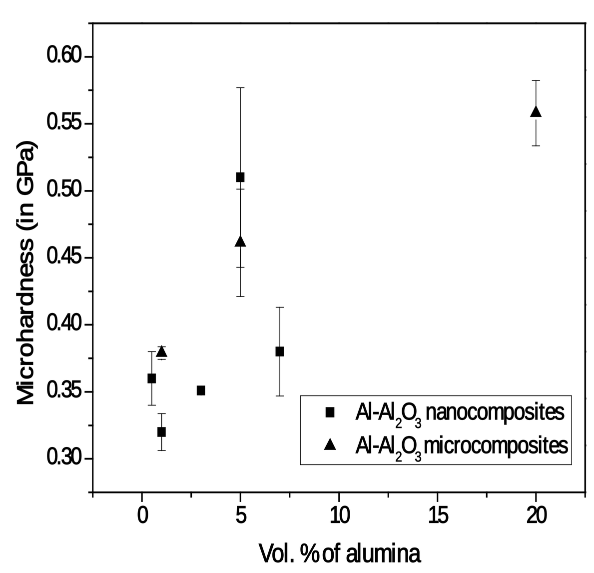


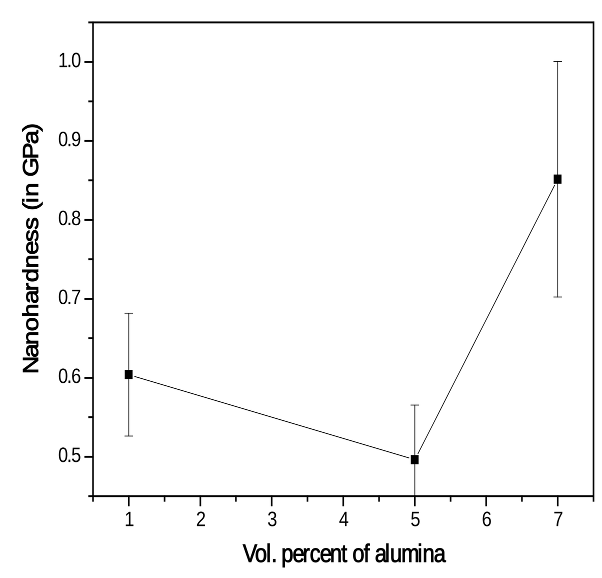
- The dislocation lines are straight, long and tangled due to heavy deformation of powder mass during spark plasma sintering process.
- High dislocation density at the sub-boundaries due to the large difference in thermal conductivity of aluminium (24 x 10^{-6}/°C) and alumina (7.92 x 10^{-6}/°C).

Al-5 vol. % Al_2O_3 micro-composite

Density and Hardness Study

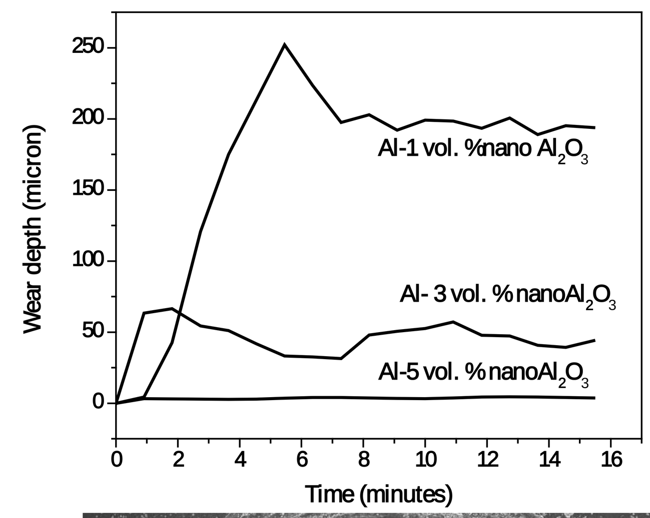


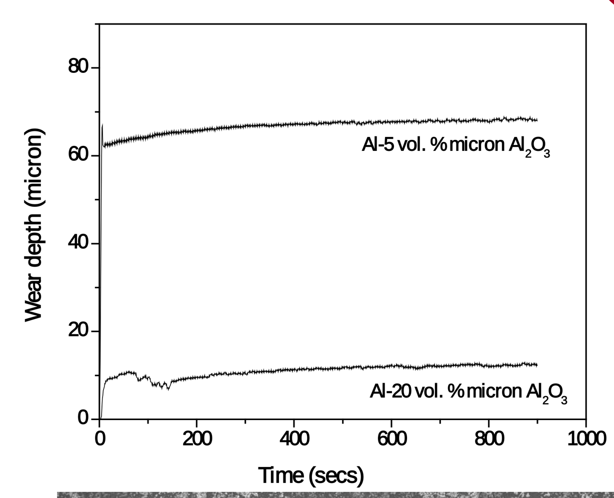


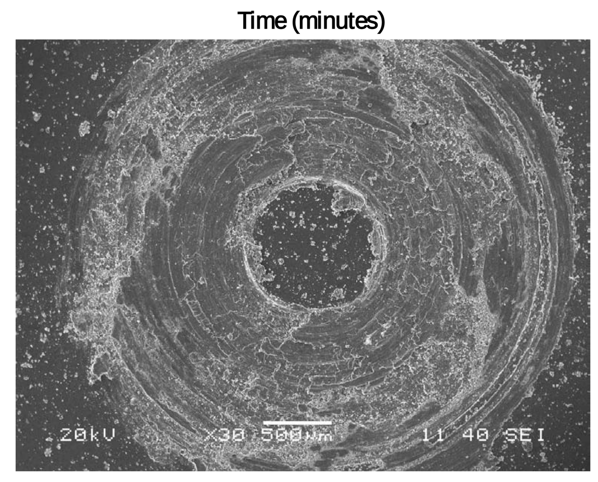


- Density of micro-composite is higher than nano-composite.
- Hardness value increases with increasing alumina content in both cases.
- Nano-indentation hardness value is higher than micro-hardness value in case of nano-composites.

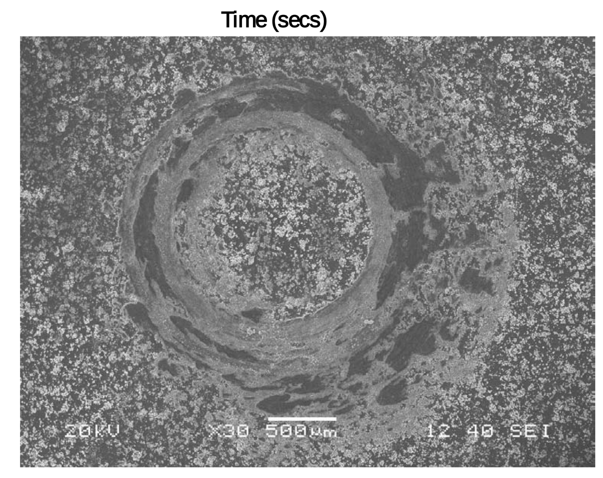
Wear Study



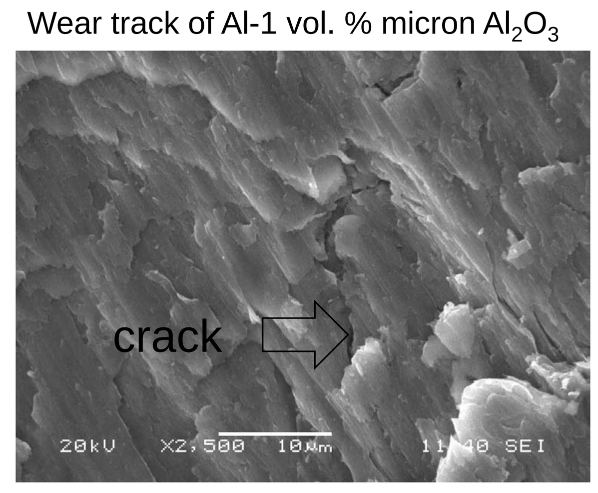




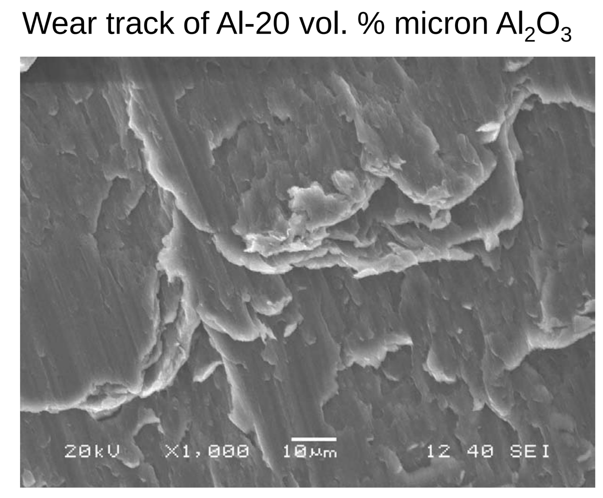
Wear track of Al-1 vol. % micron Al_2O_3



Wear track of Al-20 vol. % micron Al_2O_3



SEM micrograph of worn surface of Al-1 vol. % nano Al_2O_3



SEM micrograph of worn surface of Al-1 vol. % micron Al_2O_3

- Wear resistance of micro-composites are higher than nano-composites.
- Wear resistance increases with increasing alumina content in both cases.
- Plastic shear flow, cracking and de-lamination are predominant wear mechanisms for Al-Al_2O_3 micro and nano-composites.

Conclusions

- The compatibility of alumina in aluminum matrix in nano-composites is better than micro-composites.
- Almost full densification in case of 1 vol. % alumina reinforced nano- and micro-composites have been achieved. The density of micro-composites as well as nano-composites decreases with increasing alumina content.
- The SEM micrographs reveal a lack of intimate proximity between matrix and reinforcement entities in the case of micro-composites than nano-composites.
- The nano indentation hardness of nano-composites is higher than the corresponding micro-hardness values.
- Wear resistance of micro-composites are higher than nano-composites. Wear resistance increases with increasing alumina content in both cases.

Acknowledgements

The authors would like to thank National Institute of Technology (NIT), Rourkela for providing the necessary financial and infrastructural supports. The authors are also grateful to Prof. Bikramjit Basu, Laboratory of Biomaterials, Indian Institute of Technology, Kanpur for coordinating in the preparation of samples using Spark Plasma Sintering facility. The authors also express their gratitude to IMMT, Bhubaneswar for nano-indentation measurements.

References

1. Li Y, Zhao YH, Ortalan V, Liu W, Zhang ZH, Vogt RG, Browning ND, Lavernia EJ, Schoenung JM. Investigation of aluminum-based nano-composites with ultra-high strength. Mat. Sci. Eng. A 2009; 527:305-316.
2. Gupta M, Surappa MK, Qin S. Effect of interfacial characteristics on the failure mechanism mode of a SiC reinforced Al based metal matrix composite. J. Mater. Process. Technol. 1997;67:94-99.
3. Razavi Hesabi Z, Hafizpour HR, Simchi A. An investigation on the compressibility of aluminum/nano-alumina composite powder prepared by blending and mechanical milling. Mat. Sci. Eng. A 2007;454:89–98.

!Contact: Dr. D. Chaira (E-mail: chaira.debasis@gmail.com, Phone: +91 9438370956)

ICNT 2012, 23-27 July, Paris