CHAPTER 6

CONCLUSIONS AND FUTURE SCOPE

6.1. Overall conclusions

This chapter highlights and summarizes all the conclusions that could be drawn on the main topic "**Studies on the development of palladium and copper based nanocatalysts for sustainable Suzuki-Miyaura, Sonogashira and Chan-Lam cross-coupling reaction.**"In addition the future prospects of the existing works are also highlighted here.

6.1.1. Conclusions from Chapter 1

The main approach of this chapter is to give a general introduction on NPs of different metal and metal oxides followed by various synthetic procedures opted for their synthesis including biosynthesis approach. Literature survey dealing with the synthesis and applications of the NPs is also provided in this chapter. Apart from this a general introduction of C-C and C-heteroatom (mainly C-N) including historical background and literature review are also be a major part of this chapter. Finally, the aim and objectives of the research work have also been highlighted in the last part of this chapter.

6.1.2. Conclusion from Chapter 2

In this chapter we report a simple and green protocol for the synthesis of poly(ethylene glycol) supported Pd NPs from aqueous extract of *Colocasia esculanta* leaf extracts. The catalyst was found to be very active towards a ligand free Suzuki-Miyaura cross-coupling reaction at room temperature.

Advantages of this method are:

1. The method is considered as a green and ecofriendly method for the synthesis of Pd NPs avoiding the use of harsh chemicals for the reduction process. The phytochemicals that are present in the leaf extract act as reducing agent.
2. The nanocatalyst can successfully be applied for a ligand free Suzuki-Miyaura reaction at room temperature. The reaction is found to complete within a short reaction time.
3. The catalyst is found to be very efficient and reusable upto 5^{th} run.

6.1.3. Conclusions from Chapter 3

This chapter demonstrates the use of *Sapindus mukorossi* seed extract as a reducing agent for the synthesis of Pd NPs and its successful application in room temperature Suzuki-Miyaura cross-coupling reaction.

The major outcomes of the method are:

1. Simple and green protocols for the synthesis of Pd NPs. Mainly the phytochemicals that are present in the plant are responsible for its reducing ability.
2. No external reducing agent has been used during the process, neither any stabilizer are added. The components that are present in the seed extract itself act as reducing and stabilizing agent.
3. Effectively catalyze Suzuki-Miyaura cross-coupling reaction at room temperature with vast functional group compatibility.
4. Avoiding the uses of expensive and environmentally unfavorable organic ligands.

6.1.4. Conclusion from Chapter 4

In the present chapter, an efficient method for *N*-arylation of aniline and imidazole with aryl boronic acid as coupling partner catalyzed by CuO NPs at room temperature was presented. The CuO NPs were synthesized by using a simple thermal refluxing technique.

The chapter can be summarized with the following upshots:

1. CuO NPs can efficiently be synthesized by a simple thermal refluxing method and they have a size of approximately 12 nm of diameter.
2. The nanocatalyst can efficiently catalyze *N*-arylation of imidazole and aniline with aryl boronic acids at room temperature.
3. The procedure works well with wide varieties of electronically diversed imidazole, aniline and aryl boronic acid substrates at room temperature.
4. The catalyst is efficient and reusable up to 3^{rd} run with slight decrease of catalytic activity.

6.1.5. Conclusions from Chapter 5

This chapter is divided into two sections.

Section 5.1 In this section of the chapter 5, methanol aided synthesis of Pd NPs decorated on biosilica and its successive implication in copper free Sonogashira cross-coupling reaction at room temperature has been discussed.

The main consequences of this method are:

1. Developed a simple solvent facilitated synthesis of Pd NPs decorated on biosilica at room temperature without adding any external reducing agent.
2. The catalyst Pd-BioSiO has been synthesized at room temperature only by stirring in methanol medium. No external reducing agent, heating, ultrasonication etc being used during the synthesis.
3. The catalyst has been successfully applied for a copper and ligand free Sonogashira reaction at room temperature in *iso*-propanol. The reaction time is also very short compared to some conventional method.
4. Uses of expensive and unfavorable ligands have been avoided here.

Section 5.2 In this section, we have applied the same catalyst (mentioned in section 5.1 above) for an efficient room temperature Suzuki–Miyaura reaction between aryl halides and phenyl boronic acid substrates under ligand free reaction conditions and found that the catalyst shows excellent result.

6.2. Future Scope of the work

Based on the findings that we obtained in the preceding chapters, the future prospects of the existing works can be summarized as:

1. To synthesize different transition metal NPs (monometallic/bimetallic) like Cu, Ni etc by using different biological resources and waste materials.
2. To develop some new synthetic methods for some other organic synthetic reactions using the synthesized nanocatalyst.
3. To develop some new protocols for desulfurization cum cross-coupling reaction using the synthesized catalyst.
4. To apply the synthesized nanoparticles (mainly oxide nanoparticles) in purification of contaminated water from inorganic pollutants. Inorganic pollutants

such as arsenic, lead, chromium has harmful effects both on humans, animals as well as on environment. So, remedial measurements are in urgent need to reduce the level of these pollutants to or below the permissible limit. CuO NPs, mainly in the form of nanorods can be successfully applied for the removal of lead and arsenic from water, as it has a strong affinity for these two metals [1].

6.3. References

[1] (a) Raul, P. K., Senapati, S., Sahoo, A. K., Umlong, I. M., Devi, R. R., Thakur, A. J., and Veer, V. CuO nanorods: a potential and efficient adsorbent in water purification. *RSC Advances*, 4(76):40580-40587, 2014. (b) Goswami, A., Raul, P. K., and Purkait, M. K. Arsenic adsorption using copper (II) oxide nanoparticles. *Chemical Engineering Research and Design*, 90(9):1387-1396, 2012.