Chapter 1

Introduction and Objectives

Rapid progress in the synthesis and utilisation of functionalised polymeric materials has been noted in the recent past\textsuperscript{1-4}. Merrifield by introducing the solid phase peptide synthesis\textsuperscript{5}, paved a new path for the versatile utilisation of functional polymers in various fields. Functionalised polymers have found widespread applications in chemical, biological and technological fields\textsuperscript{6-15}. Organic synthesis using functional polymers\textsuperscript{16}, complexation and separation of metal ions using polymeric ligands\textsuperscript{17}, study of specificity of biological reactions of natural polymers\textsuperscript{18}, biomimetic catalysis\textsuperscript{19}, enzyme immobilization\textsuperscript{20}, controlled release formulations\textsuperscript{21}, conductive polymers\textsuperscript{22}, polymeric surfactants\textsuperscript{23} and stabilisers\textsuperscript{24}, polymeric liquid crystals\textsuperscript{25}, polymeric food additives\textsuperscript{26}, conversions\textsuperscript{27} and storage of solar energy\textsuperscript{28}, polymeric corrosion inhibitors\textsuperscript{29,30}, asymmetric synthesis\textsuperscript{31,32} and resolution of racemic mixtures\textsuperscript{33} are some of the important fields in which chemistry of functionalised polymers find applications. In spite of all these, the development
of combinatorial chemistry with the advent of compound library technique revolutionised the various branches of chemistry\textsuperscript{34-37}. The reactions using functionalised polymers have many advantages over the reactions of low molecular weight reagents, which make the former very popular in various academic, industrial and technological applications. Some of the merits of the polymer supported reactions are enlisted below.

- Simplified reaction work up. Simple filtration separates the excess reagent and reactant from the product.
- Higher yields of product can be achieved by using excess of soluble or polymeric reagent without causing separation problems.
- High stability and selectivity of the polymeric reagent.
- Non-volatility and non-toxicity.
- Regeneration and reusability.
- Automation is possible.

Although the earlier work involving polymer supports was concentrated on repetitive sequential synthesis such as those of polypeptides, nucleosides and polysaccharides, numerous other applications spanning a wide spectrum of chemistry have been devised and have led to a better understanding of both the advantages and the limitations of polymer supported species\textsuperscript{38,39}.

The functionalised polymers used for various applications can be categorised into three\textsuperscript{40}. Functional polymers are used as carriers for the substrates, reagents and catalysts. In the case where the polymer acts as a
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carrier, the product is attached to the polymer support throughout the synthesis, while the byproduct and excess of reagent all remain in the solution. After filtration, the product can be cleaved from the polymer support using suitable cleaving techniques. Solid phase synthesis of polypeptides\textsuperscript{41}, oligonucleotides\textsuperscript{42} and oligosaccharides\textsuperscript{43} are some of the examples of the reactions in which functionalised polymers are used as carriers.

The second type includes polymer supported reagents in which a polymer incorporating a conventional synthetic reagent function is reacted with a low molecular weight substrate which is transformed into the product. The excess of polymeric reagent and spent reagent remain with the polymer support whereas the product goes into solution. Polymer bound Wittig reagents\textsuperscript{44}, oxidising\textsuperscript{45}, reducing\textsuperscript{46}, halogenating\textsuperscript{47}, condensing\textsuperscript{48}, alkylation\textsuperscript{49} and acylating agents\textsuperscript{50} are examples of this group.

The third type includes polymer bound catalysts. The active site of the functional polymer catalyses reactions. The polymer bound transition metal catalysts\textsuperscript{51}, phase-transfer catalysts\textsuperscript{52}, Lewis acid catalysts\textsuperscript{53} and super acid catalysts\textsuperscript{54} are some examples of this category.

The utilisation of polymer supported reagents both as delivery and scavenging reagents is growing in popularity due to the simplicity of use, performance and ease of product isolation\textsuperscript{55}. The growing fascination of polymer supported reagents in synthetic organic chemistry is due to their increased stability and selectivity. As the reactive residues are anchored to the
polymer support, the reactivity and selectivity of the reagent may be changed due to the so-called ‘polymer effects’, allowing the design and synthesis of tailor-made polymeric reagents.

A wide range of polymers have been used as supports in various polymer supported reactions. They include extremely hydrophobic polystyrene and highly hydrophilic polyacrylamide. Polystyrene is the most extensively used polymer support. It’s commercial availability, ease of functionalisation, thermal stability, stability towards most chemical reagents and compatibility with a wide range of solvents account for its increased popularity over other polymer supports. But the hydrophobic and non-polar nature makes polystyrene support inadequate in the synthesis of oligosaccharides and oligonucleotides. Polyacrylamide, poly(methyl methacrylate), poly(N-vinylpyrrolidone), poly(4-vinylpyridine), polyethylene glycol and poly(vinyl alcohol) are some of the examples of polymers which are used as supports in solid phase syntheses. Natural polymers like polysaccharide based supports and inorganic polymers like silica have also been used in solid phase reactions.

The design of a new reactive polymer must be planned by considering important factors, which affect the reactivity. The nature of solvents and reagents used during the course of functionalisation and the physical and chemical behaviour of the support are significant factors which govern the reactivity and application of a functionalised polymer. The physico-chemical characteristics of the polymer support depend on the molecular character of
monomers, extent of crosslinking, nature of diluents and the method of preparation of the support. Thus, support well suited for specific applications can be designed and prepared by proper adjustment of the above factors during resin preparation.

The present work is focussed on the preparation, characterisation and synthetic utility of polymer bound ethylenediamine-borane reagent as reducing agent. Low molecular weight borane reagents such as diborane, borane-tetrahydrofuran, borane-dimethyl sulfide and amine-borane were known to be effective reducing agents. Generally amine-borane reagents have many advantages as reducing agents due to their selectivity and stability. S. Itsuno et al. have reported that low molecular weight amino alcohol-borane reagent reduces carbonyl compounds selectively in the presence of nitriles and esters and polymer bound amino alcohol-borane has a significant selectivity in the reduction of aldehydes in the presence of ketones. They have prepared polymer bound amino alcohol-borane under very controlled reaction conditions. Here, we are aimed at the preparation of polymer bound ethylenediamine-borane (EDA-borane) reagent at room temperature under mild reaction conditions in a cost effective way. The synthetic utility and selectivity of the reagent in the reduction of aldehydes were studied. The influence of the macromolecular characteristics of the polymer support, effect of solvent, temperature and presence of catalyst on the reactivity of the bound reagent function were also included in our study.
Objectives of the work

1. Preparation, characterisation and optimisation of polystyrene support with different crosslinking agents.

2. Preparation and characterisation of polymer bound EDA-borane reagent and the study of the synthetic utility of the reagent in the reduction of aldehydes and ketones.

3. Investigation of the influence of the macromolecular characteristics of the polymer such as nature of the polymer support, nature and extent of crosslinking and effect of solvent on the reactivity of the bound reagent function.

4. Studies of the effects of temperature and catalyst on the reduction reactions with polymer bound EDA-borane reagent.

5. Study of the effect of nature of amine on the reactivity of the polymer bound amine-borane reagent.

6. Preparation of polymer bound amine-borane reagent using crosslinked polyacrylamide resins and study of it’s reducing property.

Organisation of the thesis

The thesis is organised into 7 chapters. They are as described as below.

Chapter 1 Deals with a brief introduction to polymer supported reactions with special emphasis on polymer supported reagents and the objectives of the work.
Chapter 2  Forms a review on polymer supported reactions and polymer bound reagents.

Chapter 3  Describes preparation and functionalisation of the polymer supports and preparation of polymer bound ethylenediamine-borane reagent

Chapter 4  Describes reduction of aldehydes using the polymer bound ethylenediamine-borane reagent and the effect of the structural parameters of the polymer matrix and reaction conditions on the reactivity of the polymeric reagent.

Chapter 5  Includes the preparation of amine-borane reagent on crosslinked polyacrylamide system.

Chapter 6  Gives the detailed description of the experimental procedures employed for the preparation and functionalisation of crosslinked polymers and preparation of polymer bound amine-borane reagents. The chapter also includes the procedures used in the reduction processes using the polymeric reagents.

Chapter 7  Gives the summary and outlook.