From Carbon Dioxide to Recyclable Polymers and Plastics

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Polymers are some of the highest volume products of the chemical industry but their manufacturing, use and disposal causes pollution. Production alone is responsible for > 1 Gt/annum of carbon dioxide emissions, ~ 3 x more than the annual emissions of the UK. Recycling options are limited and environmental contamination by legacy plastic fragments has contaminated the planet and pervades the food chain. We urgently need to re-examine the design, production and disposal of polymers. There are many approaches to the problem, this lecture focuses on the potential for some classes of oxygenated polymers, including polycarbonates and polyesters, to overcome some of the problems posed by hydrocarbon polymers. One challenge of using oxygenated polymers is that both the understanding of their polymerization catalysis, structure-property relationships and recyclability tends to be less well developed.[1] This lecture focuses on trying to gain fundamental understanding of the chemistry of polymerization, polymers and depolymerizations. A case study on polycarbonates will be presented, including catalysis for carbon dioxide/epoxide ring-opening copolymerizations (ROCOP), how carbon dioxide can be used to improve properties of ductile plastics, polymer electrolytes and catalysed chemical recycling. In the first part, a series of different heterodinuclear catalysts will be presented, these catalysts have structures comprising M(II)M'(II) and M(I)M(III) structures, with different ancillary ligands and where M(II) = Mg(II), Zn(II), Co(II) and other transition metals, where M(I) = s-block metals like Na(I), K(I) and M(III) = Co(III) or Al(III).[2,3] Polymerization kinetics and DFT calculations are used, together with catalyst structural investigations, to support various mechanistic hypotheses and the factors controlling metal synergy in some catalysts will be discussed.[3,4] The lecture will next examine how switchable polymerization catalysis can be applied to improve the properties of carbon dioxide derived polymers and plastics.[5] It will focus on two case studies: the toughening of plastics and the production of solid state electrolytes for lithium ion batteries.[5,6] In the final part, the catalysis of depolymerization will be examined and catalysts allowing recycling to 'true' monomers will be discussed.[7,8]

References

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