Reversible Crosslinking in Functional Elastomers; Design and Properties

Abstract: Elastomers are an important class of polymeric materials used in various sectors, viz. automotive, sports, households, biomedical applications, etc. Due to several external stimuli, the elastomeric products undergo fracture, deformation, and crack formation. These waste materials are either scrapped, incinerated, or dumped into the soil, which causes serious environmental issues and an extra budget for new products. It is well-known that elastomers are crosslinked via sulfur, peroxides, metal oxides and resins. These crosslinked networks are irreversible in nature. Therefore, recycling and reprocessing of these crosslinked products have been challenging issue for the materials research community. From this point of view, it would be a great step toward sustainability if the elastomers are crosslinked via dynamic crosslinking to enhance their service life and to induct reprocessing and recyclability in the elastomer. In this context, this thesis delineates the incorporation of reversible crosslinking in functional elastomers in order to generate self-healing, recycling and reprocessing properties. For this purpose, engineering elastomers i.e., carboxylated nitrile rubber (XNBR) and bormobutyl rubber (BIIR), have been chosen for modification. The chemical processes such as Diels-Alder (DA) and retro-Diels-Alder (rDA), disulfide metathesis reaction, imine bond formation, (4π+4π) cycloaddition reaction, and ionic aggregation have been introduced in the elastomeric systems by synthesizing a new class of dynamic crosslinker as well as small molecules for the modification of elastomers. The chemically modified elastomers exhibit self-healing characteristics under different stimuli like heat, visible and UV light. Within the scope of this thesis, the self-healing and recycling capabilities of filler-loaded systems were also investigated. In this thesis, the structural, morphological, mechanical, and healing properties of modified elastomers/composites were analyzed in depth using different analytical techniques such as FTIR, ^{1}H NMR, SAXS, SEM, TEM, AFM, optical microscopy, tensile testing, and nanoindentation (NINT) etc. Thus, this thesis takes one step closer to paving a new path towards sustainable development in the field of elastomers by extending the lifespan of the materials and cutting down the wastes, which also makes a contribution to the circular economy.

Keywords: Reversible crosslinking, carboxylated nitrile rubber (XNBR), bromo butyl rubber (BIIR), Diels-Alder (DA), disulfide metathesis, ionic interaction, self-healing, recycling, reprocessing.