Upgrading biobased carbon for sustainable chemicals and materials

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Increasing energy demand and escalating environmental issues are grand challenges to overcome. Developing low-energy, clean technologies to convert biomass at low costs is critical in enabling sustainable energy and reducing carbon emissions. This talk will present our recent progress in developing novel technologies to upgrade biomass sources into sustainable chemicals and green materials. Electrified conversion technologies are receiving increasing attention due to their ability to decarbonize process heat while offering higher energy efficiency and novel reaction mechanisms. In terms of biobased chemical production, we integrated non-thermal plasma into biomass conversion to enhance product yields and lower energy inputs. By conducting plasma electrolysis in polar aprotic solvents, we completely solubilized biomass within a few minutes. During the electrified conversion, cellulose and hemicellulose were converted to levoglucosenone and furfural in high yields while lignin was transformed into a selectivity oxidized lignin in a single-step process. The electrified synthesis was also developed to convert lignin and biochar into nanocarbons. By employing a joule heating method, we produced oxygen-functionalized and highly dispersible carbon nano-onions without catalysts and solvents. Carbon nano-onions produced using different types of lignins and biochar were further applied as additives in biobased composites. Incorporating 0.1-0.5wt% of biobased nanocarbon in polylactic acid or the composites of polylactic acid and wood fibers significantly improved the mechanical, thermal, and gas barrier properties of the biobased polymers, outperforming other carbon-based additives or fillers, including carbon nanotubes. In addition to chemicals and nanocarbons, we also produce green carbon fiber using lignin as the precursor. To overcome the intrinsically defected lignin structure lacking in molecular linearity, we proposed a "deconstruction followed by controlled reconstruction" concept to transform lignin into a linear thermoplastic precursor. An arylate thermoplastic polymer synthesized from lignin bio-oil was melt-spun to obtain carbon fibers with a tensile strength of 1.7GPa and tensile modulus 182GPa. More recently, we developed a lignin-tailored fiber fabrication process to leverage the thermomechanical chemistry of lignin. Based on the newly-known chemistry of lignin, we produced melt-spun carbon fibers with a tensile strength of 2.45 GPa and a tensile modulus of 236 GPa without pre-modifying lignin.