

Microwave-Enabled Biomass Conversion for Hydrogen, Bioadhesives, and Biochar Utilization in Rare Earth Element Recovery

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This paper presents three microwave-driven catalytic processes for biomass conversion and utilization, highlighting the role of microwave catalysis in enhancing biomass conversion performance and bioproduct applications.

The first process focuses on microwave-assisted biomass gasification for hydrogen production using pinewood as the feedstock. Iron- and nickel-based catalysts were employed, and the pinewood biomass contained approximately 42% oxygen. This study examines differences in reaction chemistry, product yields, and the roles of key reactions, including the water–gas shift (WGS) and Boudouard reactions. The results demonstrate that microwave-assisted gasification offers advantages in reaction efficiency, catalyst stability, and hydrogen yield. Under microwave-assisted conditions, the gas yield reached 87%, while char and tar yields were 12.1% and 0.793%, respectively, at 550 °C.

The second process addresses microwave-enabled catalytic lignin depolymerization for bioadhesive production using glycerol as the solvent. This approach is notably rapid, achieving approximately 89% lignin conversion within a few minutes. The process is highly efficient, as the solvent is recyclable, the catalyst is regenerable, and no pressurized hydrogen is required. The resulting phenolic blend is retained during dissolution in glycerol and later incorporated into a hot-press cross-linking process with soy protein to form adhesives. Single-lap shear tests revealed a strong correlation between bonding strength and solid content. The optimized formulation, with a solid content of 68 wt.%, exhibited greater bonding strength than a commercial soy protein adhesive containing 34 wt.% solids. This study demonstrates a rapid, ambient-pressure method for converting lignin waste into a phenolic blend that can replace a significant fraction of soy protein while enhancing adhesive performance.

The third process explores the use of biochar derived from biomass pyrolysis for rare earth element (REE) recovery. Recent experiments using Appalachian hardwood biochar demonstrate the feasibility of employing ionic liquids to extract REEs from dilute, multicomponent solutions such as acid mine drainage (AMD). Regeneration studies over multiple cycles confirm that the biochar can be effectively reused. The biochar was characterized by using a range of analytical techniques to develop a mechanistic understanding of the microwave-driven REE recovery process.