

Playing defense: reaction engineering solutions for biomass conversion and catalysis

Jeremy Luterbacher

Institute of Chemical Sciences and Engineering, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Abstract

After atmospheric CO₂, lignocellulosic biomass is the second-largest source of renewable carbon on our planet. This makes biomass a very attractive source of sustainable alternatives to fossil-derived chemicals. The production of various chemicals from biomass usually involves the depolymerization of biomass's three constituent polymers: cellulose and hemicellulose, which are both polysaccharides; and lignin, which is a polymer of phenyl propanoid sub-units. These three types of complex molecules are broken down into their constituent monomers, which include sugars and phenyl propane derivatives. In turn, these low-molecular weight monomers can be catalytically upgraded to either direct or indirect substitutes for petrochemicals. In both depolymerization and catalytic upgrading, the biggest challenge is often not achieving the desired reaction, but rather avoiding being outcompeted by other, detrimental reactions. Depolymerization reactions of the major biomass constituents – polysaccharides and lignin – are often outpaced by subsequent degradation reactions of sugars and lignin intermediates. In parallel, coking reactions and catalyst deactivation processes plague the upgrading of highly oxygenated and water-miscible renewable molecules.

In this talk, I will present several solutions to these challenges that my laboratory has developed. I will show how we can use functionalization chemistry, both during lignin extraction and polysaccharide depolymerization, to reversibly “trap” stabilized intermediate molecules, and facilitate their high-yield upgrading^{1,2}. Notably, we can show that, under the right conditions, extracted lignin can be catalytically upgraded at high yields to as few as 1-2 major products^{3,4}. I will also discuss how targeted surface modifications on heterogeneous catalysts can lead to dramatic changes in activity, stability and selectivity, even in the presence of highly oxygenated renewable streams^{5–7}.

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