Over the last decades, tremendous progress has been made in the control of catalytic materials on the nanometer size scale. This includes tailoring of pore sizes of catalytic materials by different soft and hard templating techniques, size control of catalytically active metal particles by solution phase synthesis of such particles and subsequent deposition on supports, the placement of catalytic particles in desired locations of structured support materials, and the design of solid environments which resemble ligand motifs of molecular catalysts.

Most catalytic materials nowadays are based on metals and/or oxides. However, in biomass conversion the demands on the catalysts are rather different compared to those in chemistry based on petroleum feedstocks. Thus, new opportunities arise for porous polymers which allow a precise control of pore structure, surface polarity and location of catalytically active metals supported on them. Some examples for catalysts based on porous polymers will be given.

Building block concepts are highly important in the synthesis of catalysts with controlled nanostructures. If support structure and metal nanoparticles to be deposited on the supports are synthesized independently and then combined to yield the final catalyst, a high level of control can be achieved, since both components can be separately optimized. Colloidal deposition of metal nanoparticles on different supports allows the synthesis of highly active, gold-based catalysts for CO oxidation, which help to clarify the role of the support material for high activity of such catalysts.

The placement of catalytically active particles in desired locations of structured supports is an interesting technique for the creation for composites with novel properties. Iron oxide particles exclusively placed in the interior of the carbon tubes of CMK-5 are very stable and have high activity in ammonia decomposition. Hollow shell supports allow the synthesis of a variety of different catalysts with outstanding performance. Encapsulation of single metal particles in hollow shells made of zirconia, titania or carbon allows the synthesis of catalysts which are stable against sintering, since individual particles are encapsulated and therefore can not migrate towards each other, which prevents sintering. This pathway is highly flexible, if the parameters are fine-tuned, and a wide range of catalysts is accessible. An interesting variant of this process relies on the synthesis of hollow spheres of carbon with mesopores in the carbon shells. If platinum particles are deposited in the mesopores of the shell, the platinum dispersion is thermally extremely stable. Importantly, this material is also a very active and stable fuel cell catalyst, and both rotating disc electrode measurements as well as measurements using a working membrane-electrode-assembly prove the high stability of this system. The approach can be extended to allow the formation of alloyed nanoparticles by confined space alloying.

Finally, the synthesis of solids having ligand motifs of the Periana catalyst for the oxidation of methane to methylbisulfate (which can be hydrolyzed to methanol) has recently become possible. Such solids can be impregnated with suitable platinum species, upon which solid analogues to the Periana system result, with comparable catalytic activity for methane oxidation. This concept might be extendable to other catalytic systems so that a new range of solid catalysts could be synthesized.