# Miniature Doughnuts

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***A matter of capillary action: colloid crystals as molds for nanorings***

It isn't only prospective bridal couples that are interested in rings; engineers and scientists are also fascinated by the apparently near-magical properties of ring-shaped objects. For example, magnetic fields can induce a permanent eddy current in conducting rings, and a tricky mixture of rods and rings act as coils and antenna and thus lead to materials with amazing optical properties, like negative refractive indices. These phenomena are size dependent. Especially when the rings are meant to interact with visible light, it is necessary to control their size at the sub-micrometer level. But how can such tiny rings be made? Werner Goedel and Feng Yan from the Technical University in Chemnitz have developed a new "three-dimensional" strategy in which crystals act as a sort of mold for the production of rings.

Here's how their clever concept works: First, micrometer- sized spheres are slurried in a solvent and, by
centrifuging, pressed in form of regularly packed so-called colloid crystal. This just has to be dried and the "mold" is complete. In the next step, the scientists infiltrate the mold with a polymer solution, such as polystyrene in chloroform. Their special trick is to only partially fill the form. The liquid then doesn't sink to the bottom; instead, it creeps into the tiny crevices around the contact points between the spheres and collects in the form of little rings.

This phenomenon is caused by capillary forces - the same forces that allow water to rise inside a narrow tube, for example. If the solvent is

then evaporated, the polystyrene stays behind in the crevices as a solid. In the final step, the researchers dissolve the spheres. The tiny polystyrene rings of uniform shape and size left behind are reminiscent of doughnuts or asian coins. The rings can be made of a number of different materials and their size can be varied by changing the diameter of the spheres that are used. The researchers were thus able to produce mini-"doughnuts" of different polymers and ceramics and vary the outer diameter between about 400 nm and 150 nm and the inner diameter between 150 and 50 nm.

"Our new process is also very interesting," says Goedel, "because we do not produce the little rings conventionally one by one on a flat support, but all at once in a three- dimensional mold. This new method dramatically improves the space-time yield."