A new approach for fabricating dental crowns may transform the dental industry.

Scientists Developing **New Dental Materials**

Oklahoma State University doesn't have a material science department, but it does have world-class material scientists collaborating on research leading to the development of new materials for high-tech applications. Jim Smay, assistant professor in the Chemical Engineering Department at OSU-Stillwater, one of the nation's most promising young scientists and engineers, teamed with expert materials scientist, Jay Hanan, an assistant professor in the Mechanical Engineering Department at OSU-Tulsa working on strain related to ceramics, to develop new materials for dental crowns.

Smay was first exposed to the "robocasting technique" he uses in his research today while completing his graduate degree as an intern at Sandia National Laboratories. The printing process he has perfected is much like writing with a pen only automated. Smay designs a structure using a CAD program and prints it with a robocasting technique. The ink he has developed is a ceramic material much like toothpaste with the ability to hold its shape. So half the technology he is working on is making the ink. The difference in the ink in the printer he uses and an inkjet printer is the density. An inkjet printer uses ink that is 3 to 5% solids, and Smay uses ink that is 45 to 47% solids.

▼ Smay uses one of his CAD drawings that he then prints with inks he has perfected with his robocasting technique.

Photo by Erika Contreras

Smay has refined the ink formulation and processing steps to yield inks that can produce a wide range of geometries, including space filling solids, high-aspect ratio walls and self-supporting spanning structures. He uses advanced materials like aluminum and zirconium oxides blended with water and polymers to make the ink with the right flow properties. The details of the ink formulation depend intimately on the surface chemistry and concentration of the ceramic particles, pH of the water and chemistry of the polymers. The ink is extruded through a tip that is seven thousandths of an inch in diameter. The tip is immersed in oil during printing so that the printed ink won't dry until the entire part is finished. Finally, the part is removed from the oil, dried and baked in a kiln to produce a dense, high-strength dental crown.

Different ceramic materials are used for different applications based on such properties as strength and electrical behavior. Smay uses aluminum oxide for dental crowns because of their high strength and wide acceptance in the dental community. He used barium titanate and lead zirconate titanate for photonic band gap structures and sensors. A biocompatible ceramic, hydroxy appetite, is being used to develop bone scaffolds that can be implanted in the body so bone cells will grow into pore space and make new bones.

The complete 'rapid prototyping' process Smay calls 'art to part' takes only 24 hours. He received a $400,000 National Science Foundation grant to advance the science and conduct an outreach program targeted at high school students. In July 2006, he received the Presidential Early Career Award for Scientists and Engineers for his research accomplishment and contributions in education.

With a National Institutes of Health subcontract, Smay is working with the New York University (NYU) Department of Dentistry to develop the new approach for fabricating dental crowns. He is collaborating with Hanan who works with X-ray micro-tomography and micro-diffraction. Smay is utilizing the capability of the printing process to print inks of different ceramics to build composite crowns and improve their fracture properties. The premise of the design is that by strategically placing the right ceramics in the right locations in the dental crown, residual stress may be controlled to arrest cracks that would normally destroy the crown. Hanan takes these samples to Argonne National Laboratory (ANL) where they are tested using the synchrotron.

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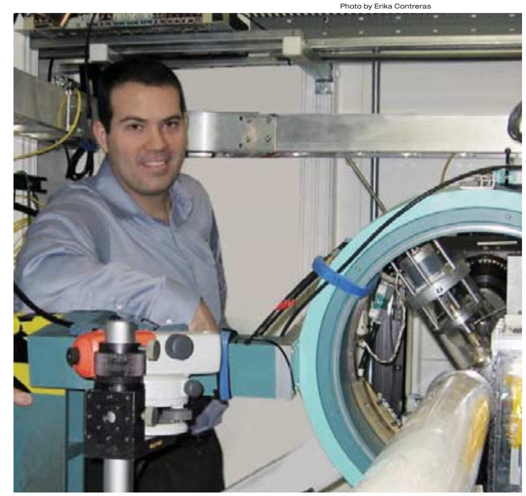
Hanan and two of his graduate students recently came back from testing samples at Argonne's Advanced Photon Source—the synchrotron which gives researchers access to X-rays. Researchers apply for beam time on the synchrotron by submitting a proposal. Hanan's proposal for beam time was accepted which allowed him to focus on this concept of ceramic materials and how they deform. Hanan is looking at aluminum and zirconium composites which are what Smay makes with his robocasting technique.

Photo by Erika Contreras



▲ Hanan tests dental materials using the synchroton located at Argonne National Laboratory.

Some things you can see with the beam line can't be seen with any other tool. There are also advanced third generation beam lines in Japan and Europe, but there are no others offering the same capabilities as the one at ANL. Hanan looks at strain and damage in these materials which is how a material responds to stress and contact fatigue. Hanan says the ability to look deep within the material using synchrotron X-rays can't be done in any other lab without cutting through the material which then destroys it. This falls into the non-destructive evaluation area—a graduate course taught by Hanan at OSU. The 3-D images created using a synchrotron are high resolution. "You can see atoms in motion with the beam line," says Hanan.

According to Hanan, this research is exploratory, but it could grow into a four-year program. NYU doesn't know the residual stress of the crowns Hanan is testing. "But if we can determine the stress, we can use it in a way to make better crowns," says Hanan.

Jana Smith