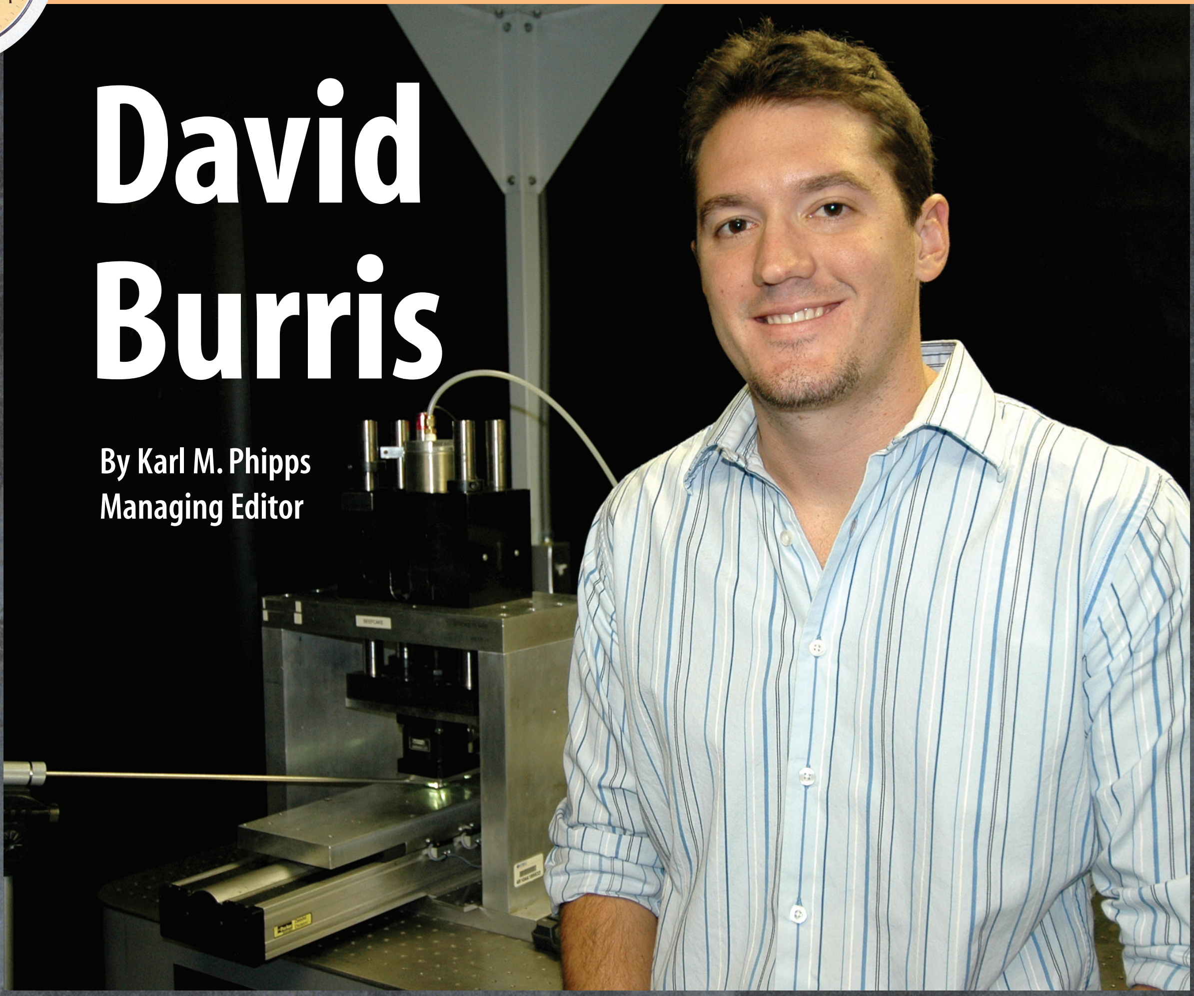
20 Minutes With...



David Burris

By Karl M. Phipps
Managing Editor

Already making major contributions to our understanding of tribological phenomena, this University of Florida doctoral candidate makes a strong argument for the value of STLE to students.

Professional experience

- Harris Corp., Melbourne, Fla. Component level testing of new materials for harsh environments and cryo tribology on PTFE-based solid lubricants, 2005-present.
- W.L. Gore & Associates, Inc., Newark, Del. Studied ultra-low wear PTFE to enable design and development of engineered PTFE solid lubricants, 2003-present
- Mako Surgerical Corp., Fort Lauderdale, Fla. Developed and studied candidate materials for use in novel orthopedic implants, 2005.
- E-One, Ocala, Fla. Did investigation and optimization of linear ladder bearings, 2004.
- John Deere, Moline Ill. Studied abrasive wear to improve lives of grain combine blades, 2003.
- FMC, Houston, Texas. Designed the primary support bushing to allow relative motion of the oil transport shaft and survive the life of the oil supply for an off-shore oil rig, 2003.
- Author of 30 technical papers and presentations.

Education

- University of Florida, Gainesville, Fla. Master's of Science in Mechanical Engineering, 2006.
- University of Florida, Gainesville, Fla. Bachelor's of Science in Mechanical Engineering, 2003.

How did you first get exposed to tribology, and what made you want to pursue a career in this field?

Besides taking an introductory physics course, my first exposure to tribology came during my third-year design class at the University of Florida. At the time I had never been exposed to graduate education or research and never really considered graduate school as an option. We toured a handful of research laboratories that included the tribology lab. I was very interested in the various research efforts I saw (robotics, gas dynamics, manufacturing, etc.) until we got to the tribology lab.

There were some machines running, and it appeared that they were rubbing materials together to measure friction coefficients. I was amazed that such a lab existed and wondered how many material combinations they could come up with to keep their research going. I could find friction coefficients for materials that people actually used in my design book: cast iron-on-cast iron—dry 0.2; wet 0.05, powdered metal-on-hard steel—dry 0.3; wet 0.05 and carbon graphite on steel—dry 0.25, wet 0.05. Until then, WD-40 was the universal solution to my tribology problems, and I remember wondering why anyone would choose to spend their days measuring friction coefficients.

Next semester I took a class on fluid dynamics, which was taught by STLE member Dr. Greg Sawyer. Toward the end of the semester, he asked me if I would be interested in doing an undergraduate research project where I would design and build a knee simulator to obtain pressure maps for various positions of the joint. I thought Dr. Sawyer was an excellent teacher, and I enjoy design, so I decided to take him up on the offer. I was in the lab quite a bit designing the kinematics, setting up the servo-hydraulic load frame and hanging around other students. I started picking up bits and pieces of what they were doing and why it was important.

In undergraduate design, there was always an answer; the modulus of elasticity, yield strength and coefficient of friction were always known properties, and I chose the materials that gave me the best all-around performance. I never needed to design a joint whose performance had an unknown dependence on humidity, temperature and vacuum level. I found that I enjoyed working on problems without known solutions and thinking about the complex interactions that occur at the sliding interface of two surfaces. Soon thereafter, the engineering research I previously enjoyed seemed uninteresting by comparison.

CONTINUED ON PAGE 22

Awards and Honors

- **_ASME Journal of Tribology_ Best Paper Award for "Wear Rate Uncertainty Analysis"—Presented at the 2004 ASME/STLE International Joint Tribology Conference, Long Beach, Calif.**
- **NSF Research Experience for Undergraduates Grant, May 2003.**
- **University of Florida President's Honor Roll (4.0 GPA), 2000-2004.**

Patents

- **"Low Friction, Low Wear Polymer/Polymer Composite," (Inventors: W.G. Sawyer and D.L. Burris): UF11603—Patent Application No. 10/914, 615.**
- **"Multi-Layer Low Friction and Low Wear Polymer/Polymer Composites Having Compositionally Graded Interfaces," (Inventors: W.G. Sawyer and D.L. Burris): UF11767—Patent Application No. 10/140, 775.**
- **"Invert Wear Resistant PTFE-Based Solid Lubricant Nanocomposite," (Inventors: W.G. Sawyer and D.L. Burris): UF11839— Patent Application No. 11/443, 384.**
- **"Low Cost Nanocomposite Solid Lubricant," (Inventors: W.G. Sawyer, D.L. Burris, N.L. McCook and B. Boesel): UF11945—Patent Application No. 11/385, 062.**
- **"_In-Situ_ Lubrication of Sliding Electrical Contacts," (Inventors: W.G. Sawyer, J.C. Ziegert and D.L. Burris): UF11766—Patent Disclosure.**
- **"PTFE Surface Treatment to Increase Wear Resistance," (Inventors: W.G. Sawyer and D.L. Burris): UF12146—Patent Disclosure.**

CONTINUED FROM PAGE 21

Was tribology adequately covered in your undergraduate curriculum?

The word 'tribology' was not once mentioned in my undergraduate program. We learned about friction coefficients in the context that friction leads to efficiency losses, heat and excess loads, all of which needed to be accounted for. It was a very simple extension of what we were already learning. We did discuss the use of rolling element bearings in design, the statistical estimation of life and implementation and specification of bearings in design. The Reynolds Equation for one-dimensional flow and hydrodynamic journal bearings also were briefly addressed.

Though not discussed in class, there is a brief description of dry bearings and wear estimation nestled in the back of my design book. Theses cursory introductions gave me the impression that friction and wear were trivial annoyances and only mentioned for the sake of completeness. In reality, it is quite the opposite. This seems to be the situation at many, if not all institutions. Tribology is a very multidisciplinary science and really does not have an obvious home in chemistry, materials science or mechanical engineering. Very few mechanical systems operate without sliding interfaces, yet only a very small fraction of mechanical engineers coming out of school have any knowledge of tribology aside from the properties that are misleadingly tabulated in design handbooks. Even the most basic rules of thumb, like avoiding steel-on-steel contact, are foreign to most.

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Fortunately, I am at one of a few universities with a faculty member, Dr. Sawyer, who specializes in tribology. Our graduate program does offer classes on fluid film lubrication, rough surfaces, wear and contact mechanics, but few students outside the tribology lab ever take these classes. Until students are exposed to tribology, many view it more as an inconvenience than a science, much as I did as an undergraduate.

Your doctoral research is in the area of nanostructured tribomaterials. Describe that research.

My master's thesis was on the tribology of polytetrafluoroethylene (PTFE) nanocomposites. PTFE is an interesting material to study from a tribological standpoint. It is well-known for its very low friction coefficients, but because it wears 10-100 times faster than many other materials (in general), it is only used in neat form for semistatic applications.

For about the last 50 years, ordinary hard particle and fiber fillers have been used to reduce the wear of PTFE. These composites have acceptable wear resistance for many applications, but the fillers often abrade the counterface and transfer films, leading to third body wear, asperity plowing and increased friction coefficients. The goal of my research was to use the unique attributes of nanofillers to engineer bulk wear resistance into PTFE at very low loadings.

When my research began in 2003, the general consensus reflected a previous size study by Tanaka et al.(1) that concluded that submicron particles were less effective wear reducers in a PTFE matrix than microparticles. The hypothesis was that small particles were unable to provide load support because they are easily swept away within the matrix as debris due to the large relative size of the contacting asperities. However, three papers (Li et al.,(2) Chen et al.(3) and Sawyer et al.(4) that all came to print around that time described the processing and tribological results of different PTFE nanocomposites. In each case, the nanocomposites had similar wear rates to comparably loaded (~20 wt %) PTFE microcomposites.

These studies laid the foundation for my research and raised general questions about the mechanisms of wear resistance in PTFE. The fact that nanoparticles were effective at all seemed to indicate that they were arresting cracks in the subsurface rather than providing preferential load support. It was also interesting that similar properties were obtained at similar loadings of micro- and nanoparticles.

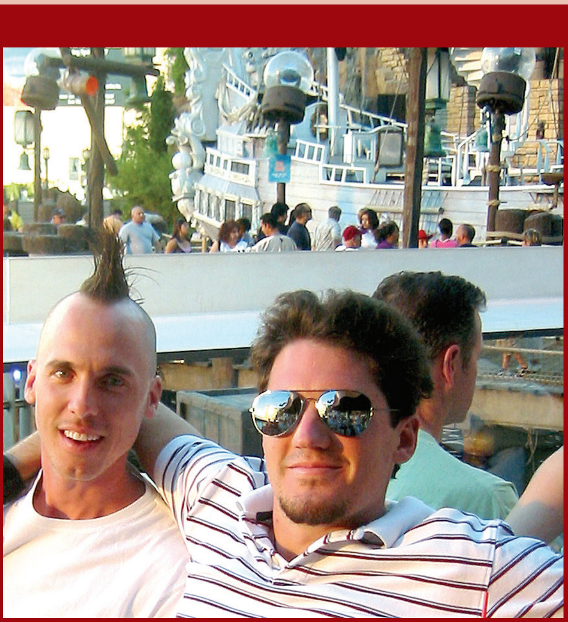
One of the key aspects of nanoparticles is the dramatic increase in the number of particles and the surface area of those particles for a given loading over microparticles. Effective crack arresting was hypothesized to occur at significantly lower volumetric loadings of nanoparticles than of microparticles. It was thought that poorly dispersed or agglomerated nanoparticles may act as microparticles.

My work initiated with the use of a more energetic and industrially scalable mixing technique (jet-milling) in order to improve dispersion of the nanoparticles. Alumina was selected for the nanoparticle material due to its chemical inertness. The idea was to create a model hard point defect, eliminating the potential variable of chemistry, and limiting the environmental sensitivity of the composite.

My first experiments investigated the counterface roughness effects on 1-10 wt% alumina nanocomposite samples of varying particle size. The results showed increased wear resistance with increased nanoparticle loading. The wear rate was found to be insensitive to counterface roughness due to the formation of stable transfer films. Very low wear rates at low loadings were not observed though. We hypothesized that the particle matrix interface was inherently weak due to the inertness of the constituents.

The next study investigated the effects of mechanical entanglement between the PTFE and alumina. The nanoparticles in the previous study were round for control and 70:30 delta:gamma phase. We found alpha phase alumina particles to be very faceted, and suspected that this shape would increase mechanical entanglement with the PTFE and improve the strength of the interface.

The results reflected the original hypothesis, showing an order of magnitude improvement in steady state wear over typical microcomposites with only 1 wt% nanoparticle loading. This work transferred into the development of a PEEK/PTFE material that was an order of magnitude more wear-resistant than the most wear-resistant material we had previously tested in the lab.



Pictured is Dave Burris with STLE member Greg Sawyer, professor of mechanical engineering at the University of Florida. The unusual hair style donned by Greg was cut by his lab students, who he brought to the 2005 Annual Meeting in Las Vegas, after the announcement of his tenure and promotion at the university.

How focused is your research on the understanding of tribological phenomena? Are there any closely related practical applications you're addressing?

There would be no need for fundamental research without the prospect of technology transfer to application. While being a member of the tribology lab at Florida, I have worked on projects for a number of companies, including E-One (fire truck manufacturer), John Deere, FMC, Mako Surgical Corp., W.L. Gore and Harris Corp.

The primary driving force in our lab is currently space tribology. One of the major challenges in space tribology is the successful operation in both terrestrial testing

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CONTINUED ON PAGE 24

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and on-orbit operation. The few materials that perform well in vacuum are poisoned by species in our atmosphere (MoS_2, for example). There are also a number of other applications that would benefit from technology that enables the design of environmentally insensitive solid lubricants.

For about the last year, I have been working with engineers at W.L. Gore and Harris on materials development and industrial scalability and the transfer of those materials into mission critical components. Being involved in the most applied areas of tribology has been a fun and exciting experience for me. As much as I enjoy seeing the fundamentals transfer to industry, my motivation is to gain a more complete understanding of tribological phenomena.

My primary goal right now is understanding the mechanisms that prohibit or promote ultra-low wear in PTFE-based solid lubricant systems. Until now, I have pursued a path led by very simple hypotheses, and we have created, perhaps fortuitously, some astonishingly low-wear, PTFE-based systems.

But PTFE is inherently complex, and developing a fundamental understanding of the mechanics at the sliding interface of a PTFE nanocomposite tribosystem is a daunting task. Recently we began an interdisciplinary collaboration that is critical to this goal, linking chemists, materials scientists and mechanical engineers.

The work is still in the early development stage but already has been very fruitful. It is reinforcing the complexity of the system, suggesting that performance depends on the synergism of coupled mechanical, morphological and chemical effects in the bulk solid as well as the transfer film. Disruption of any one favorable property may increase wear by orders of magnitude. We have collectively found that additions of microparticles to a nanocomposite system destroys the favorable attributes of the nanoparticles, abrading the counterface, prohibiting transfer film development and increasing wear by ~100 times.

We recently studied the effects of a fluorine functionalization on the nanoparticles and found that ultra-low wear behavior can be preserved down to 0.25 wt% loading. The performance of the non-functionalized control nanocomposite became high and erratic at that loading. We believe that the functionalization improves dispersibility of the nanoparticles.

A study on the role of crystalline morphology added interesting insight to why irregular alpha phase alumina might outperform spherical delta:gamma alumina. A 1 wt% alumina-PTFE nanocomposite with a wear rate of $k = 6 \times 10^{-8}$ mm^3/Nm was given a simple heat treatment to remove a hypothesized microstructural signature of ultra-low wear PTFE. After heat treatment, the wear rate was $k = 6 \times 10^{-6}$ mm^3/Nm, while unfilled PTFE has a wear rate $k = 6 \times 10^{-4}$ mm^3/Nm. Although the mechanical effects of the nanoparticles alone reduced wear by 100 times, the addition of the beneficial microstructure induced by these particular nanoparticles reduced wear by an additional 100 times.

The chemistry at the sliding interface also has been shown to impart wear resistance. Despite being extremely chemically resistant, PTFE can be degraded at low wear sliding interfaces. These films are thin, and as wear rates decrease, the residence times of the tribo-films increase along with the frictional energy input. We have emulated this degradation on the surface of an unfilled PTFE sample and found that wear was reduced by 100 times. This degradation likely contributes to the wear resistance of the system.

We are beginning to see consistencies of the crystalline phase and morphology using DSC, XRD and AFM with the literature for toughness in PTFE. Small lamellae, disordered structure and retention of a fibrillated structure after processing seem to be requisites of ultra-low wear PTFE. We are very excited by our initial findings and believe we are honing in on the wear mechanisms at the most fundamental levels. I feel fortunate to be a part of such a capable and diverse team, studying PTFE at a level that

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would be impossible for me to do otherwise.

As a student STLE member, you have presented several papers at both the society's Annual Meeting and the International Joint Tribology Conference. What opportunities do you think attracts students to want to join an organization like STLE?

I think that at the basis of any research effort is the desire to impact the societal understanding of something that previously was not well understood. Publishing one's work in a respected scientific journal like *Tribology Transactions* is a great way to disseminate a study, but there are so many journal publications to choose from that readers may overlook reading papers that are published by students in favor of more well-known authors.

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Where do you see yourself in your career in the next five years, and how has STLE helped you in your professional development?

I think I would have a good career working in anything from field engineering to basic research. I have particularly enjoyed the diversity and freedom of the research I have been involved with in the laboratory environment.

In five years, I see myself possibly working in a research faculty position running a laboratory and conducting experiments with students. I hope to use the knowledge I've obtained during both my undergraduate and postgraduate education to design solid lubricating systems for multifunctionality, while continuing to probe the fundamentals of the sliding interface and the resulting friction and wear.

One of the biggest impacts STLE has had in my career is that it has provided me with an opportunity to network with people whose research I've followed and who I personally respect and admire. In addition, I've been exposed to the top researchers in tribology, their scientific approach, experimental methods and the equipment and capabilities they use to conduct their research.

My interactions with members at the annual meetings have continued to shape the way I think about and conduct my own research. These interactions have created contacts and collaborations that, I hope, will transfer to my professional career. They've also refreshed my interest in my own research. What good are exciting findings if you have no one to share them with? By being involved in STLE, I really enjoy thinking about how to do my experiments, and how to analyze and present the results at the next annual meeting. **<<**

References

(1) Tanaka, K. and S. Kawakami (1982), "Effect of Various Fillers on the Friction and Wear of Polytetrafluoroethylene-Based Composites," *Wear*, **79**, pp. 221-234.

(2) Li, F., Hu, K., Li, J. and Zhao, B. (2001), "The Friction and Wear Characteristics of Nanometer ZnO-Filled Polytetrafluoroethylene," *Wear*, **249**, (10-11), pp. 877-882.

(3) Chen, W.X., Li, F., Han, G., Xia, J., Wang, L., Tu, J. and Xu, Z. (2002), "Tribological Behavior of Carbon-Nanotube-Filled PTFE Composites," *Tribology Letters*, **15**, (3), pp. 275-278.

(4) Sawyer, W.G., Freudenburg, K.D., Bhimaraj, P. and Schadler, L. (2003), "A Study on the Friction and Wear of PTFE-Filled with Alumina Nanoparticles," *Wear*, **254**, (5-6), pp. 573-580.

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