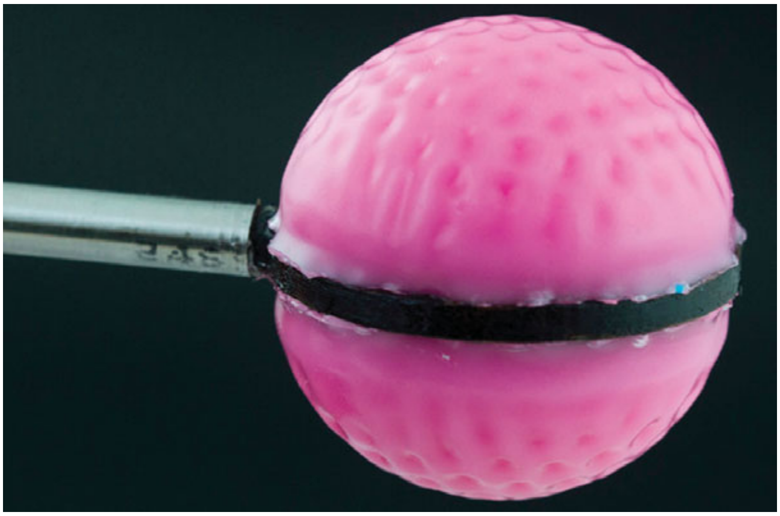
Smart morphable surfaces can dimple at will

The odd dimpled surface of golf balls is no accident—in effect, the cratered surface reduces the turbulent, drag-producing wake behind the flying ball, allowing it to travel farther. Now, researchers at the Massachusetts Institute of Technology (MIT) have created smart morphable surfaces, or "Smorphs," which can mimic the surface of golf balls. The surface of the spherical samples is made out of a silicone-based material and is initially smooth, but can become reversibly dimpled at will, altering its aerodynamic properties to best deal with the air drag it's experiencing.

"We came up with a new class of surfaces, which allowed us to switch, on demand, the aerodynamic performance and wind loading of bluff objects," said MIT engineer Pedro Reis, lead author of the study published in the June 23 online edition of *Advanced Materials* (DOI: 10.1002/adma.201401403). "It has potential applications for any object that is blunt or bluff and experiences wind loading," he said, adding that applying the surface to a vehicle or airplane could help increase fuel efficiency by reducing drag forces.

Wrinkling is currently an area of active research in the fields of mechanics and materials, which shouldn't be too surprising given that it's a common phenomenon seen in nature. For instance, a plum, which has a soft inside and an outer skin that's stiff and thin, wrinkles when it dies. Its innards shrink, putting compressive forces on the thin skin that cause it to bend in a wrinkled pattern. Interestingly, most of the research looking into wrinkling has been done on flat substrates. Studies have shown that such surfaces can have numerous different patterns of wrinkling, such as stripes, checkerboards, labyrinths and, sometimes, dimples. But much less is known about how curvature affects the wrinkling pattern of a surface. To find out, Reis and his colleagues, Denis Terwagne and Miha Brojan, set out to make a spherical Smorph, a process that involved three steps.

In the first step, the team created the outer thin shell of their Smorph by first hot-vacuum-forming hemispherical molds out of polystyrene sheets and then coating them with polydimethylsiloxane (PDMS). After they poured their polymer into the mold, they rotated it until the surface was fully wet, and then turned it upside down to drain out the excess mold. The thin, rigid shell had a constant thickness due to the balance between gravity, viscosity, surface tension, and polymerization rate. In the second step, the team created the soft foundation of their Smorph by first pouring vinyl polysiloxane or Ecoflex into their mold. Next, they covered their mold with an acrylic disk, which had an attached three-dimensional-printed part to produce a cavity in the Smorph core. In the final step, they demolded the sample.



By depressurizing the inner cavity of the rubber-like Smorph with a pneumatic system, the surface of the material can quickly become dimpled at will, and switched on and off and tuned in a fully reversible way. The radius of the spherical Smorph is 20 mm. Credit: Pedro Reis, Denis Terwagne, Miha Brojan.

To wrinkle the surface of the Smorph, the researchers depressurized its inner cavity using a pneumatic system connected to a vacuum pump. As with a drying plum, this depressurization compressed the Smorph skin, resulting in a dimple-patterned surface—the pattern can be switched on and off and tuned in a fully reversible way because of the rubber-like materials used, Reis notes. "We then had one of those 'aha' moments of realizing that our dimpled surface looks like golf balls," he said. The team systematically tested the Smorph in a wind tunnel, comparing the performance of smooth and dimpled Smorph surfaces. They found that the dimples reduced drag in a similar way to the dimples on a golf ball.

"Smorphs can fill the gap between the MEMS [micro-electromechanical system] actuators and conventional actuators," said Kwing-So Choi, a fluid mechanics researcher at the University of Nottingham, UK, who wasn't involved in the research. "The Smorphs are more robust than fragile MEMS actuators. So, there could be Smorphs applications for aeronautics, particularly UAVs, such as for flow separation and maneuverability control." However, Choi stresses that the structural strength of the Smorph needs to be improved before it can find aeronautic applications.

In the future, Smorphs could find a wide variety of applications, such as being applied to the exterior of automobiles or the surface of radar antenna domes, to help protect them from strong winds that can cause the structures to buckle. Though the researchers have only created spherical Smorphs so far, they are now looking into applying the Smorph design to other shapes.

Joseph Bennington-Castro