Inspired by steel, nanomanufacturing gets wear-resistant carbide tip

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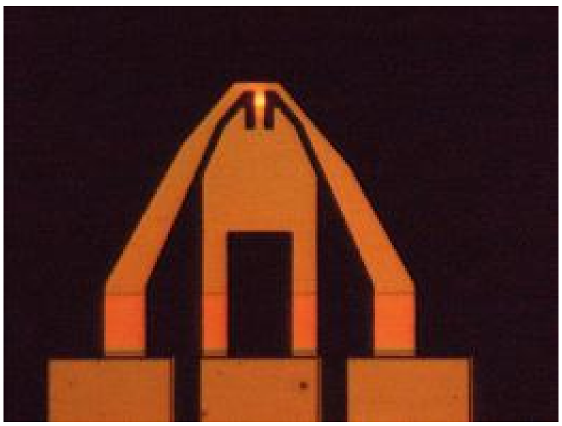

In this photo, carbon and silicon sharpened to a nano-sized tip integrated on the end of a silicon microcantilever for use in atomic force microscopy. The tip is heated to approximately 800 degrees Celsius, making it glow in this photo.

(PhysOrg.com) -- Scientists at the University of Pennsylvania, the University of Wisconsin-Madison and IBM Research - Zurich have fabricated an ultrasharp silicon carbide tip possessing such high strength that it is thousands of times more wear-resistant at the nanoscale than previous designs. The new tip, which is 100,000 times smaller than the tip of a pencil, represents an important step towards nanomanufacturing for applications, including bio sensors for healthcare and the environment.

The search for hard materials to extend the working life of sharp tools is an age-old problem that started with the first chisels used in stone carving. Eventually iron was discovered and steel tools revolutionized the era. Today, the challenge remains the same, but on a much smaller scale--the need for a nano-sized tip that is both ultrasharp, yet still physically robust, particularly under extreme temperatures and harsh chemical environments.

"The dream tip material for thermomechanical nanofabrication should have a high hardness, temperature stability, chemical inertness, and high thermal conductivity," said Dr. Mark Lantz, manager in storage research at IBM Research - Zurich. "With this novel tip we continue to deliver on IBM's vision of a smarter, instrumented world with microscopic sensors monitoring everything from water pollution to patient care."

Extending their previous successful collaboration, scientists at the University of Pennsylvania, the University of Wisconsin-Madison and IBM Research - Zurich have developed a new, resistant nano-sized tip that wears away at the rate of less than one atom per millimeter of sliding on a substrate of silicon dioxide. This is much lower than the wear rate of conventional silicon tips and its hardness is 100 times greater than that of the previously state-of-the-art silicon oxide-doped diamond-like carbon tips developed by the same collaboration last year.

"Compared to our previous work in silicon, the new carbide tip can slide on a silicon dioxide surface about 10,000 times farther before the same wear volume is reached and 300 times farther than our previous diamond-like carbon tip. This is a significant achievement that will make nanomanufacturing both practical and affordable," said Prof. Robert W. Carpick, University of Pennsylvania.

To create the new tip, scientists developed a process whereby the surfaces of nanoscale silicon tips are exposed to carbon ions and then annealed so that a strong silicon carbide layer is formed, but the nanoscale sharpness of the original silicon tip is maintained. Although silicon carbide has long been known as an ideal candidate material for such tips, the unique carbon implantation and annealing process made it possible to harden the surface while maintaining the original shape and ensuring strong adhesion between the hardened surface of the tip and the underlying material--similar to how steel is tempered to make it harder.

Consisting primarily of carbon and silicon, the tip is sharpened to a nano-sized apex and integrated on the end of a silicon microcantilever for use in atomic force microscopy. The importance of the development lies not only in its ability to maintain the sharpness of the tip and its resistance to wear, but also in its endurance when sliding against a hard substrate such as silicon dioxide. Because silicon--used in almost all integrated circuit devices--oxidizes in the atmosphere, forming a thin layer of its oxide, this system is among the most relevant for emerging applications in nanolithography and nanomanufacturing applications.

More specifically, scientists hope that the new tip can be used to fabricate bio sensors, for example for managing glucose levels in diabetic patients or monitoring pollution levels in water.

Probe-based technologies are expected to play a predominant role in many such technologies. However, poor wear performance of the tip materials used so far, especially when slid against silicon oxide, have previously limited their usefulness for experimental applications.

The next step for scientists is to begin testing the new tip for use in applications, starting with nanomanufacturing.

The study, published today in the peer-reviewed journal *Advanced Functional Materials*, was conducted collaboratively by Dr. Mark A. Lantz and Dr. Bernd Gotsmann, IBM Research - Zurich; Tevis D. B. Jacobs, Dr. Papot Jaroenapibal, Prof. Robert W. Carpick, University of

Pennsylvania; and Sean D. O'Connor and Prof. Kumar Sridharan, University of Wisconsin.

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