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Super nanowire composite solves 'valley of death' riddle

March 12 2013

(Phys.org) —In a world first, a team of researchers from Australia, China and the US has created a super strong metallic composite by harnessing the extraordinary mechanical properties of nanowires.

Co-author and Head of the School of Mechanical and Chemical Engineering at The University of Western Australia, Winthrop Professor Yinong Liu, said the work has effectively overcome a challenge that has frustrated the world's top scientists and engineers for more than three decades, nicknamed the "valley of death" in nanocomposite design.

"We know that nanowires exhibit extraordinary mechanical properties, in particular ultrahigh strengths in the order of several gigapascal, approaching the theoretical limits. With the fast development of our capability to produce more in variety, more in quantity and better in shape and size of nanowires, the chance of creating bulk engineering composite materials reinforced by these nanowires has become high," Professor Liu said. However, all the attempts to date have failed to realise the extraordinary properties of the nanowires in bulk materials.

Professor Liu says the problem is with the matrix: "In a normal metal matrix-nanowire composite, when we pull the composite to a very high stress, the nanowires will experience a large elastic deformation of several per cent. That is OK for the nanowires, but the normal metals that form the matrix cannot. They can stretch elastically to no more than 1 per cent. Beyond that, the matrix deforms plastically," he said.

Plastic deformation damages the crystal structure at the interface between the nanowires and the matrix. In this regard, the properties of the composite are limited by the properties of the ordinary matrix, and not determined by the extraordinary properties of the nanowires.

"The trick is with the NiTi matrix," Professor Liu said. "NiTi is a shape memory alloy, a fancy name but not totally new. It is no stronger than other common metals but it has one special property that is its martensitic transformation. The transformation can produce a deformation compatible to the elastic deformation of the nanowires without plastic damage to the structure of the composite. This effectively gives the nanowires a chance to do their job, that is, to bear the high load and to be super strong. With this we have crossed the 'valley of death'!" Professor Liu said.

Using this idea, the researchers have created composite materials that are twice as strong as high strength steels, that have elastic strain limits up to six per cent - which is 5-10 times greater than the elastic strains of the best spring steels currently available - and a Young's modulus of ~30 GPa, which is unmatched by any engineering materials so far.

The breakthrough opens the door for a range of new and innovative applications. The very low Young's modulus matches that of human bone, making it a much better material for medical applications as implants, for example. The ability to produce and maintain extremely large elastic strains also provides an unprecedented opportunity for "elastic strain engineering", which could lead to improvements in many functional properties of solid materials, such as electronic, optoelectronic, piezoelectric, piezomagnetic, photocatalytic and chemical sensing properties.

"A Transforming Metal Nanocomposite with Large Elastic Strain, Low Modulus and High Strength" has been published in the journal *Science*.

Provided by University of Western Australia