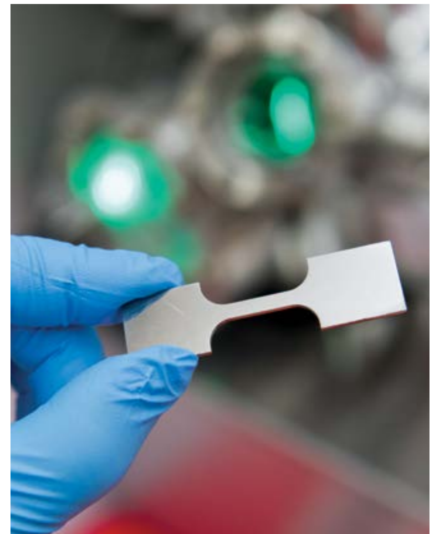

The new super alloy developed by CityU-led research is extremely strong, yet ductile and flexible.

3D-printed ceramic precursors printed with the novel ceramic ink are soft and stretchable, enabling complex shapes, like origami.

The new tiny modulator drives data at higher speeds and lower costs. © Second Bay Studios/ Harvard SEAS

PUTTING ON THE PRESSURE IN MATERIALS

Breakthroughs in materials science by researchers at CITY UNIVERSITY OF HONG KONG (CityU) demonstrate huge potential for industrial applications.

For decades, scientists have been striving to create a strong material that can withstand significant plastic deformation before rupture. CityU researchers have now developed a method for creating extremely strong alloys that are ductile and flexible — crucial properties for technological advancement.

CityU is home to an interdisciplinary group of talented scientists and engineers who have made many breakthroughs in advanced and novel materials. Four out of the ten CityU faculty members honoured as Highly Cited Researchers for 2018 by Clarivate Analytics, Paul Chu Kim-ho, Alex Jen Kwan-yue, Andrey Rogach and Wang Feng, are outstanding scholars in materials science.

Solving the strength–ductility trade-off

The new alloy achieving a compromise between strength and ductility was developed by a team led by Liu Chain-tsuan, a Distinguished Professor at CityU. In a recent study published in *Science* , his team added aluminium and titanium to form large precipitates in an iron–cobalt–nickel (FeCoNi)–based alloy, resulting in a new high-entropy alloy called Al7Ti7, which is five times stronger than the conventional FeCoNi-based alloys, and 1.5 times more ductile.

Since the deformation of high-strength alloys can easily cause fractures, the team added complex nanoparticles of nickel, cobalt, iron, titanium and aluminium atoms to achieve extended uniform deformation.

Liu believes the new alloy will perform well in temperatures ranging from -200°C to 1000°C. "It will pave the way for developing new cryogenic devices, as well as aircrafts and high-temperature systems," he says. "It has great aeronautical engineering applications."

Pioneering 4D ceramic printing

Ceramics are too brittle for easy casting or shaping. It is difficult to produce ceramics with complex shapes using existing 3D printing technology. A CityU team led by Lu Jian, CityU's Vice-President (Research and Technology) and Chair Professor of Mechanical Engineering, solved the problem by developing the world's first 4D printing for ceramics .

The team created a novel 'ceramic ink', a mixture of polymers and ceramic nanoparticles. The soft ceramic precursors printed with this ink can be stretched three times beyond their initial length, enabling complex shapes, resembling origami folding.

4D printing usually means the objects can re-shape themselves over time due to external stimuli. Combining 3D printing with programmable pre-strain, the team made use of the elastic energy stored in the stretched precursors for shape morphing. "When we relax this force, the shape will change to the anticipated form," says Lu.

The potential applications of 4D-printed ceramics are vast, ranging from 5G mobile phones, to turbine blades, or propulsion components in aerospace.

Elasticity in nano diamond

Diamonds at the nanoscale can undergo ultra-large, fully reversible elastic deformation, an international team, led by CityU, found. Up to 9% of tensile elastic strain was recorded for single crystalline samples, very close to the maximum theoretically achievable strain for an ideal diamond crystal.

This ground-breaking finding, led by Lu Yang, an Associate Professor in Mechanical Engineering at CityU, changes the common understanding of diamond. It heralds great promise for their applications, in biomedical and nanomechanical engineering, photonics and optoelectronics, Lu says.

Advanced materials for communications and sensing

The team at CityU's State Key Laboratory of Terahertz and Millimeter Wave is working to create communications and sensing devices.

With advanced nanofabrication technologies, Cheng Wang, Assistant Professor in Electronic Engineering, and his team, have created lithium niobate photonic devices with ultralow optical losses, improved performance, which use much less power. An example is the electro-optic modulator with a much smaller footprint than its traditional counterparts. Their work, published in *Nature* , is compatible with wafer-scale manufacturing processes, promising cost-effective solutions in data communications.

New techniques have also been developed to engineer crystal domain orientations with micrometre-scale precision on a chip of one centimetre. This is crucial for achieving ultra high-efficiency optical wavelength conversion and bright single-photon sources, with many applications in classical and quantum optics.

Johnny C. Ho, Associate Professor in Materials Science and Engineering, and his team, have established different methods to manipulate, process and engineer various nanomaterials, such as 1D semiconducting nanowires and 2D transition metal dichalcogenides, for new functions and properties in electronics, optoelectronics and sensors, and energy-harvesting. In contrast to the conventional 2D growth along the substrate surface, rough-surfaced substrates can manipulate the nucleation of grown materials to obtain large-scale, high-density and freestanding nanosheets for high-performance photodetection. Their nanowire parallel arrays are being investigated for developing highly efficient photoconductive terahertz optoelectronics.

A hub for neuron scattering activities

Neutron scattering is a powerful tool for examining materials at the atomic level, such as atom positioning, spacing, and interaction. Collaborating with the Chinese Academy of Sciences (CAS), the CAS–CityU Joint Laboratory on Neutron Scattering Science and Technology provides advice and technical support to the construction of the China Spallation Neutron Source (CSNS), a major facility built in Guangdong province.

The joint laboratory has solved many problems in materials research. Research led by Wang Xun-li, the lab director and Chair Professor of Physics, has ended a 40-year mystery by revealing a hidden amorphous phase in palladium-nickel-phosphorus (Pd-Ni-P) metallic glasses where atoms have a different kind of packing. This allows using simple processing methods to develop new materials.

Wang is currently studying the structure and dynamics of disordered materials, such as liquid and glass, and the effect of disorder on their properties. Collaborating with Dongguan University of Technology and CSNS, he is working on a total scattering instrument to further the studies on disordered materials.

"Given the proximity to CSNS and its rising scientific opportunities, Hong Kong can become a regional hub in neutron scattering science," says Wang. "And CityU can play a leading role." ■

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(852) 3442 7654
vprt@cityu.edu.hk
www.cityu.edu.hk

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