

范范
雲雲
深忽
鎖來
天失
子樓
山巒

納米之美
100nm

Yang Huiying

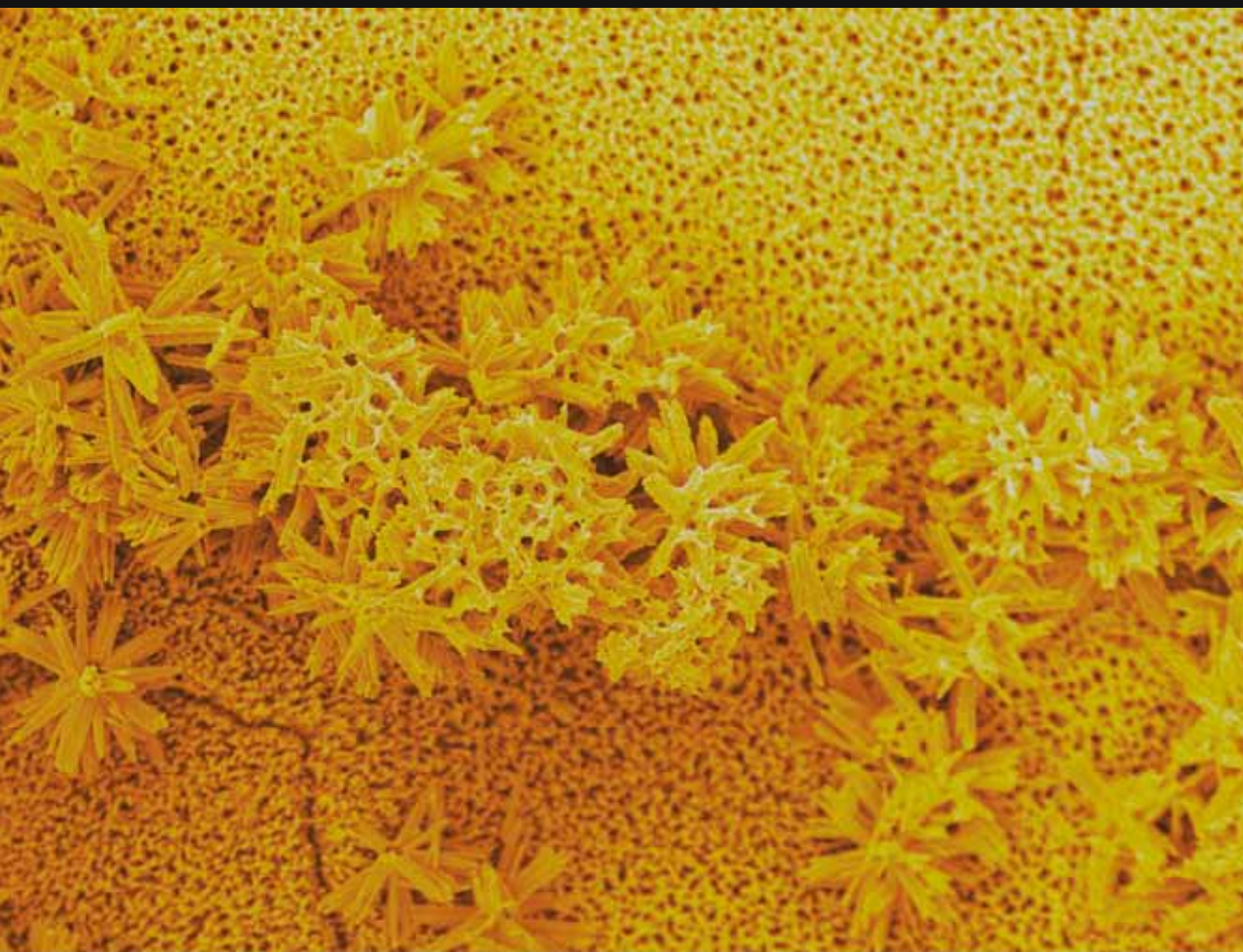
Small is beautiful

Nanomaterials are functional structures designed at an atomic or molecular scale with at least one characteristic dimension meaningfully measured in nanometers.

Zinc oxide (ZnO), tin oxide (SnO_2) and titanium oxide (TiO_2) nanostructures exhibit novel and significantly improved electrical and optical properties because of their feature size. These nanomaterials can be potentially used as lasers, LEDs (light emitting diodes) and water purification systems with improved efficiency or as very small scale devices.

Chinese Painting

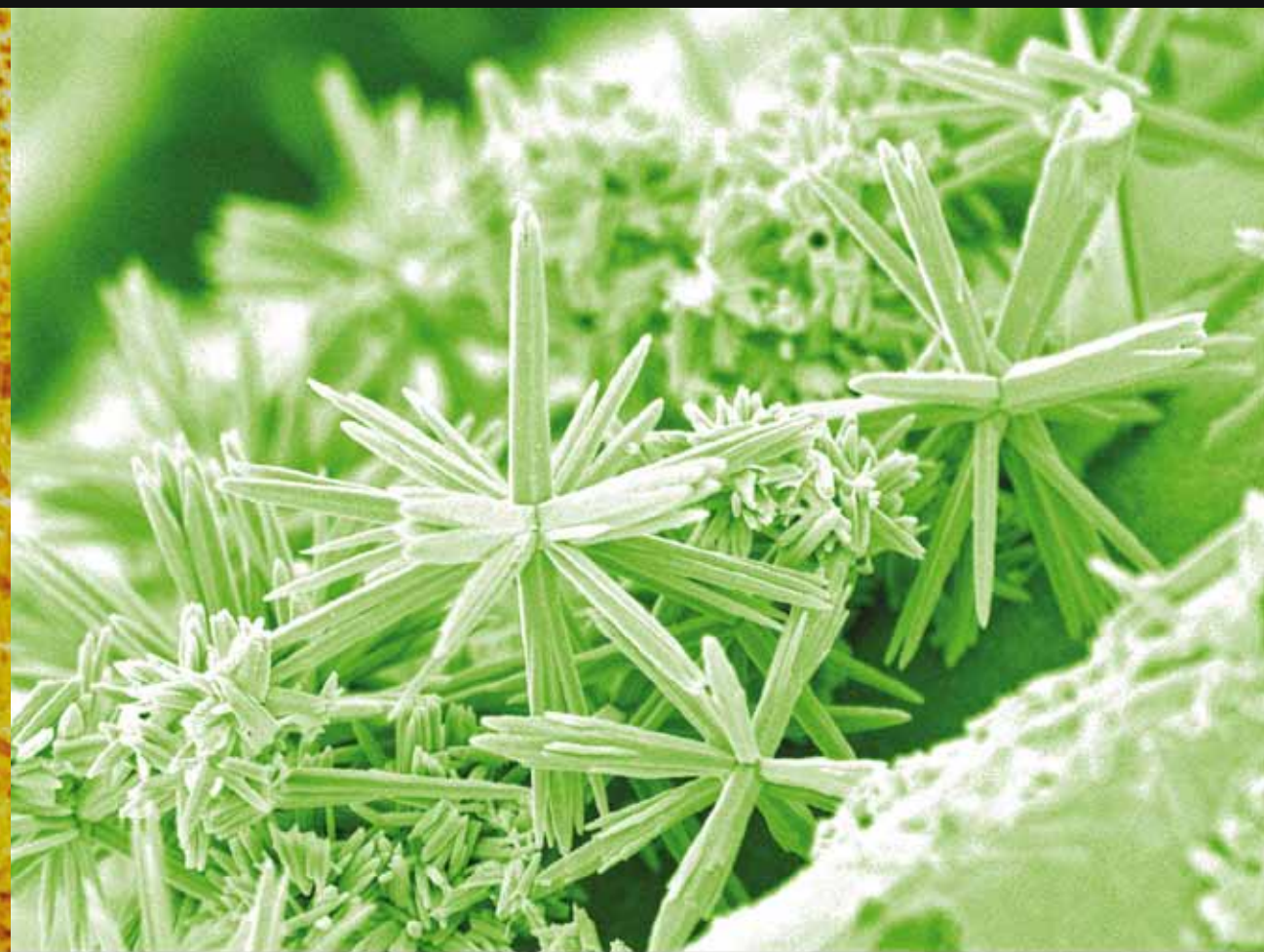
Behold the vast parallels in nature, as suggested by this serene image of zinc oxide nanoneedles created by ion beam sputtering. It was imaged using a SEM and processed to create an interesting close-up of our natural world.



SEI $\times 2,500$ $10\mu\text{m}$ WD 8mm

Autumn

SEM image of zinc oxide nanoflowers on zinc oxide nanowires.



SEI $\times 6,000$ $1\mu\text{m}$ WD 8mm

Bosk

SEM image of zinc oxide nanoflowers on a zinc oxide thin film
- fabricated by the hydrothermal method.

Hydrothermal synthesis is used to fabricate single crystals, by manipulating the solubility of minerals in hot water under high pressure. The crystal growth is performed in an apparatus consisting of a steel pressure vessel, called an autoclave, in which a nutrient or precursor is supplied along with water. A gradient of temperature is maintained between the opposite ends of the growth chamber so that the hotter end dissolves the nutrient/precursor and the cooler end causes crystals to seed and grow.

Chemical Vapour Deposition (CVD) is an on-line coating technology integrated directly with the desired substrates. CVD technology can be specifically designed to efficiently produce nanostructures. In the CVD process, reactive precursors are vapourized into a carrier gas stream. The resulting vapour feed is directed to the hot surface of a substrate (generally 800°C) where the vapour reacts to form a coating. The advantages of CVD include a high deposition rate and high degree of control of processing conditions and resulting film structures.

Electrodeposition is the process of producing a usually metallic coating on a surface by the action of an electric current. The deposition of a coating

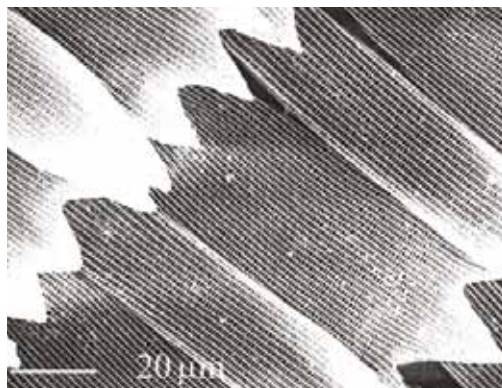
onto an object is achieved by putting a negative charge on the object to be coated and immersing it into a solution which contains a salt of the metal to be deposited (in other words, the object to be plated is made the cathode of an electrolytic cell). The metallic ions of the salt carry a positive charge and are thus attracted to the object. When they reach the negatively charged object (that is to be electroplated), it provides electrons to reduce the positively charged ions to metallic form.

All these methods are well established and so simple and easy to handle for the purpose of growing novel nanostructures for analysis.

Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) techniques were used to investigate the morphology of these samples. The images help me to understand my sample's structure and their possible usage. Sometimes, I found these images behold the vast parallels in nature, so I coloured them and processed them to create an interesting close-up of our natural world.

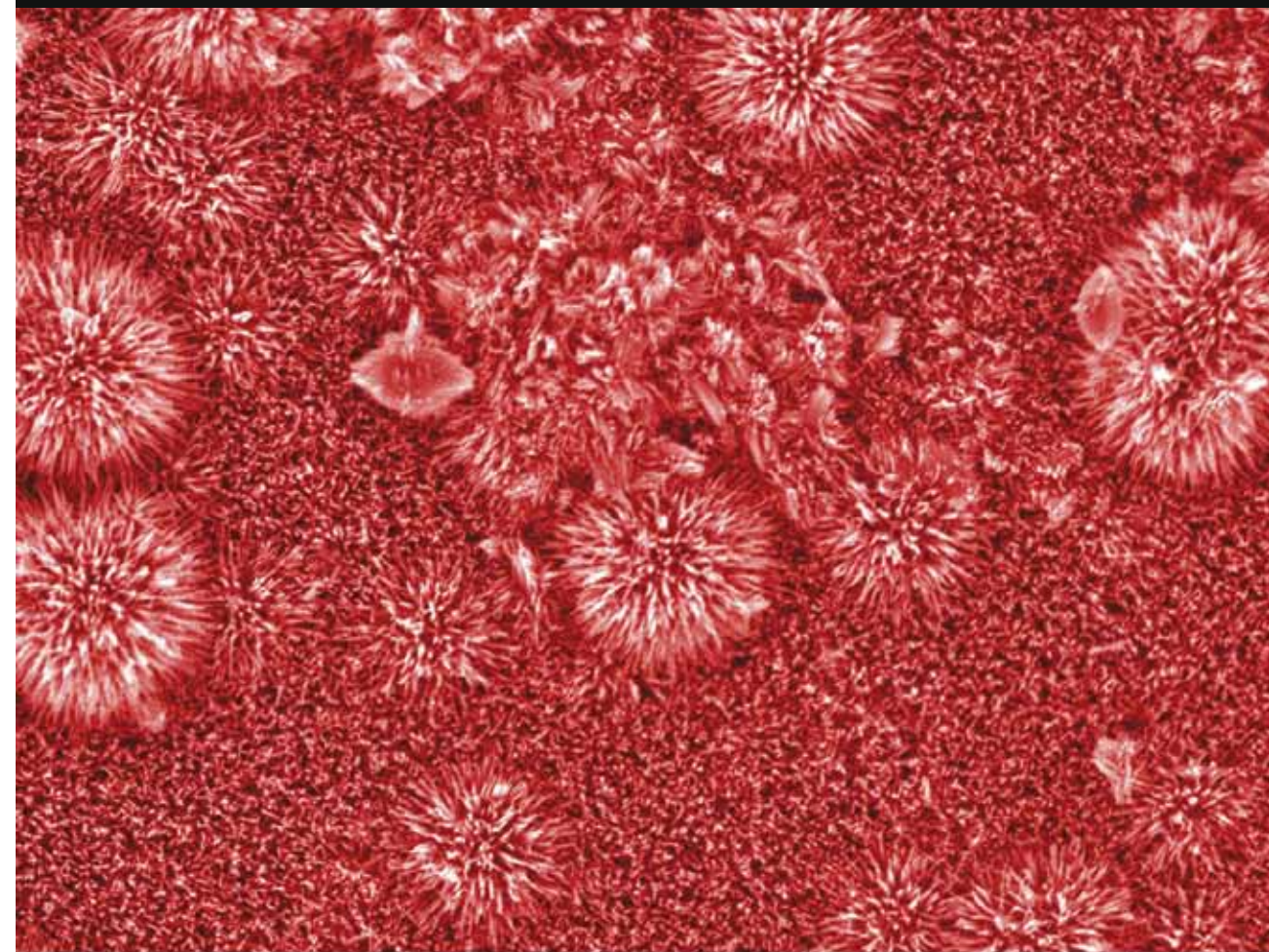
“Yang Hui Ying, an electrical engineering student at Nanyang Technological University in Singapore, is one cutting edge crusader... Ms. Yang has unearthed the right materials to create more cost-effective flexible lasers. Her work could lead to flexible lasers becoming more widely used.”

- The Asian Wall Street Journal



Butterfly wing

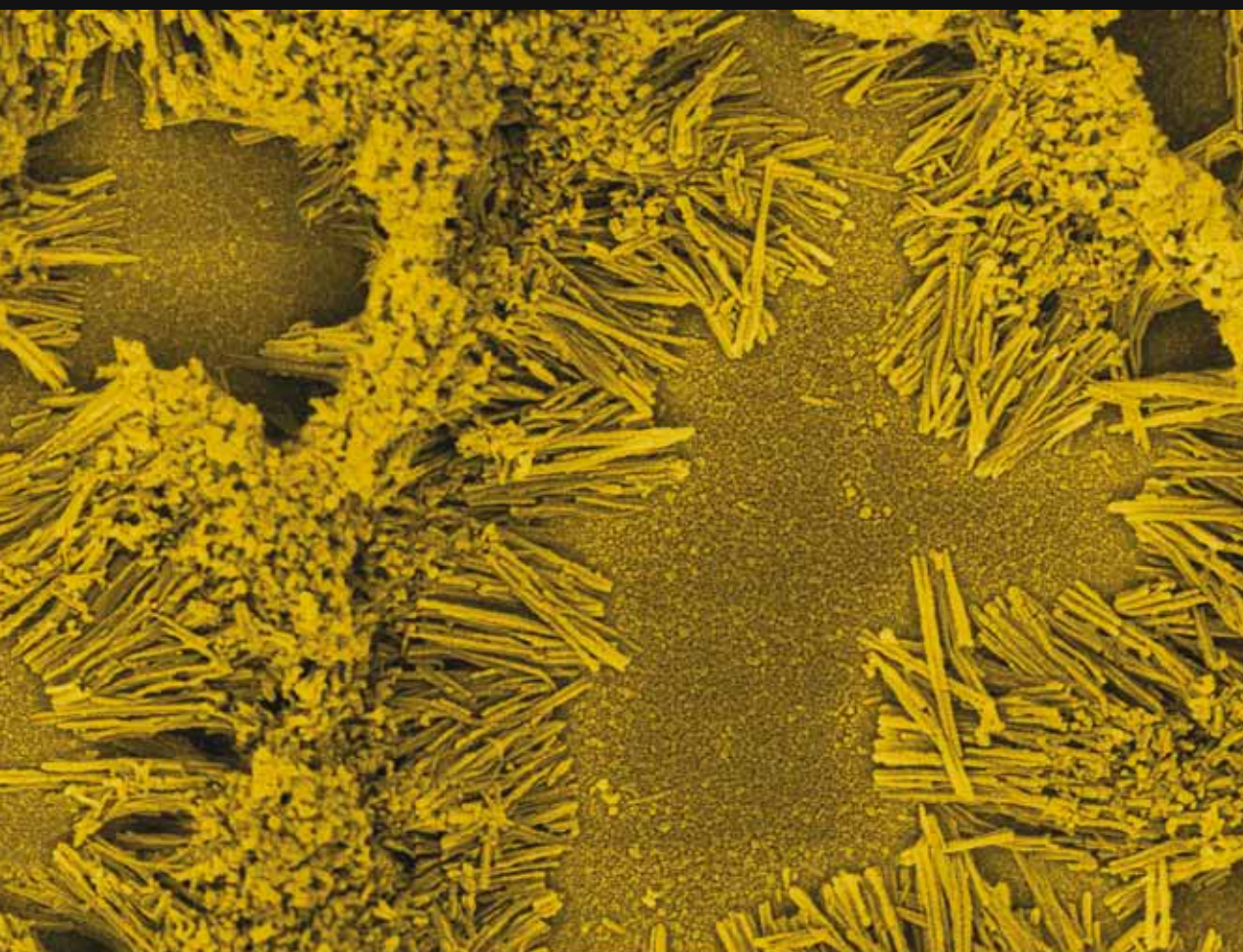
Real butterfly wing covered with ZnO thin film.



SEI 5.0kV x10,000 1µm WD 6mm

Cactus in the Desert

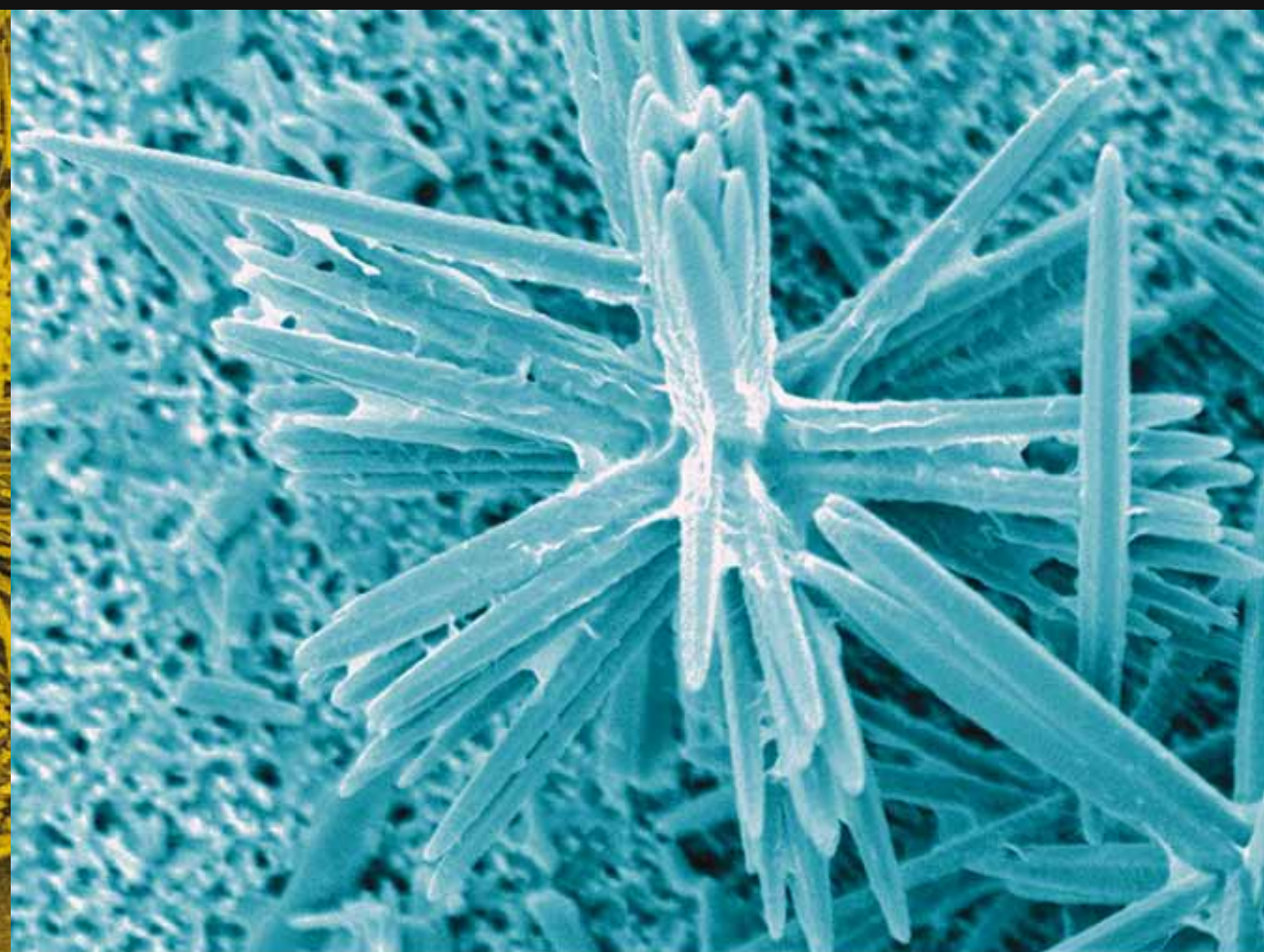
SEM image of zinc oxide nanoflowers on a zinc oxide thin film - fabricated by the hydrothermal method.



SEI 5.0kV $\times 18,000$ $1\mu\text{m}$ WD 7mm

Crop Circles

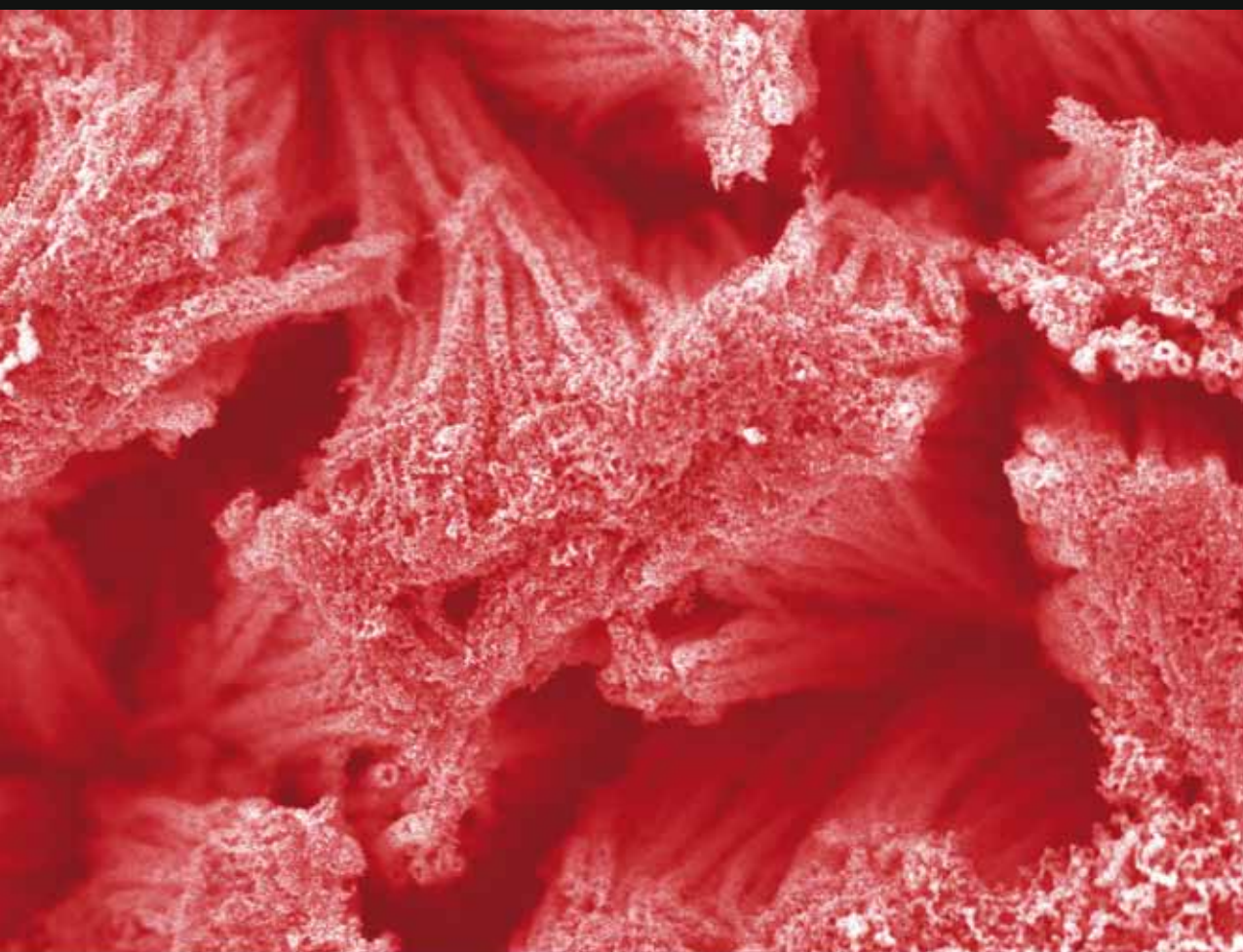
SEM image of zinc oxide nanowires. The nanowires are prepared by electrodeposition into nanopores of an anodized aluminum oxide (AAO) template on a silicon substrate.



SEI $\times 11,000$ $1\mu\text{m}$ WD 8mm

Flower in Sea

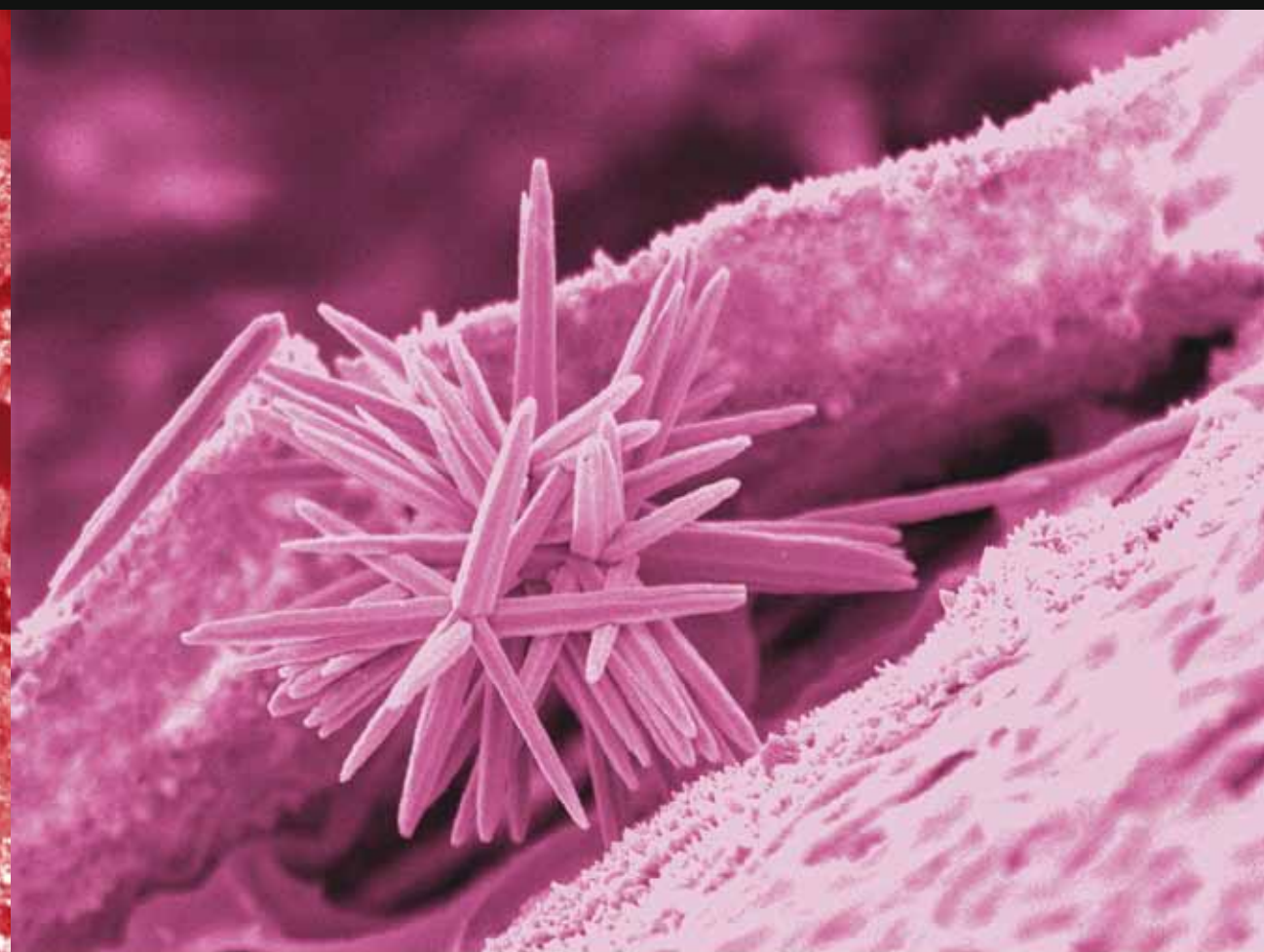
SEM image of zinc oxide nanoflower on a zinc oxide thin film - fabricated by the hydrothermal method.



SEI $\times 11,000$ $1\mu\text{m}$ WD 6mm

Go with the Wind

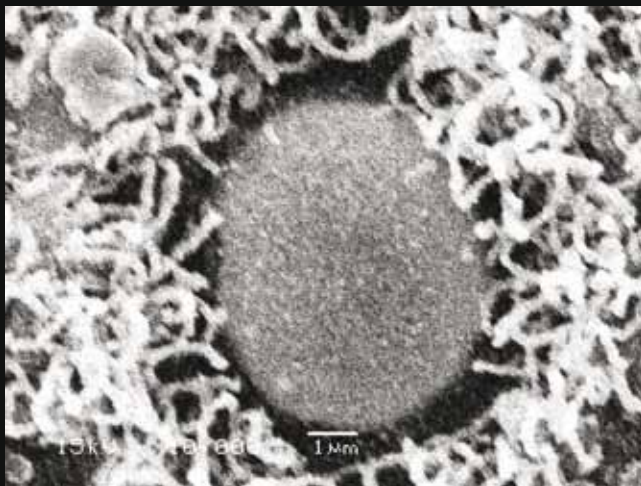
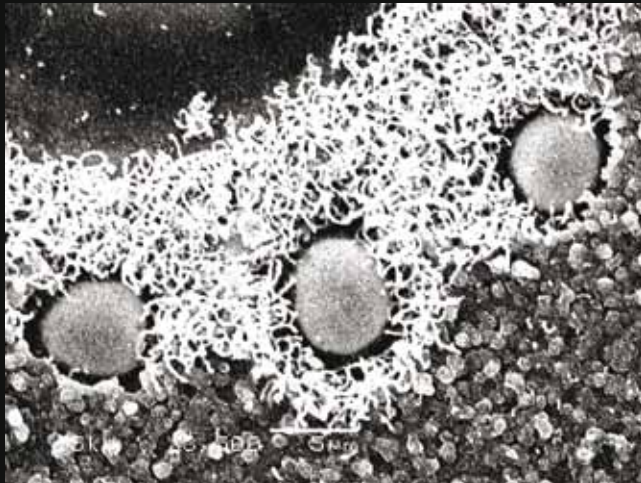
SEM image of porous titanium oxide nanotubes - fabricated by the hydrathermal method.



SEI $\times 8,000$ $1\mu\text{m}$ WD 8mm

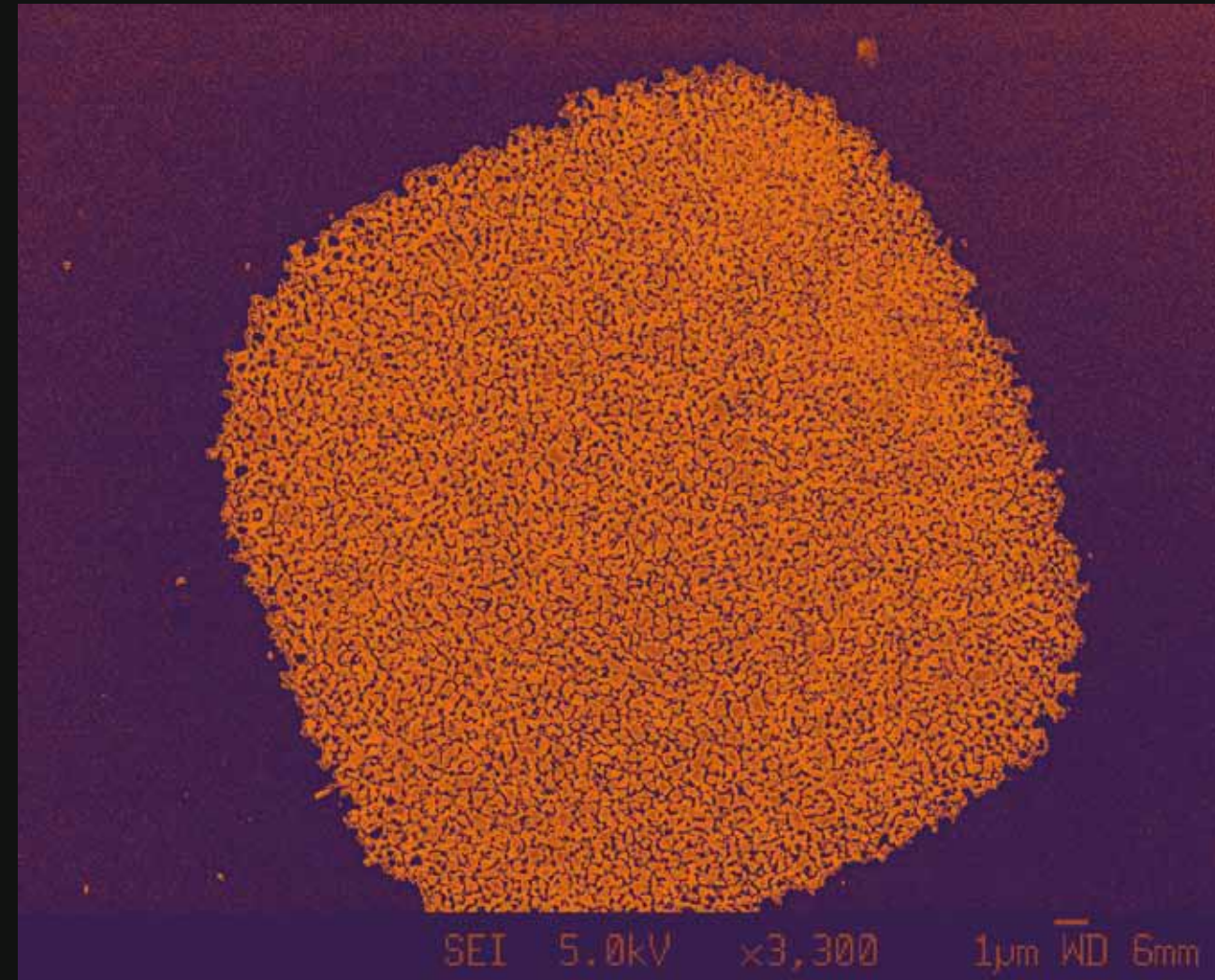
On the Edge

SEM image of zinc oxide nanoflower under a zinc oxide thin film - fabricated by the hydrothermal method.



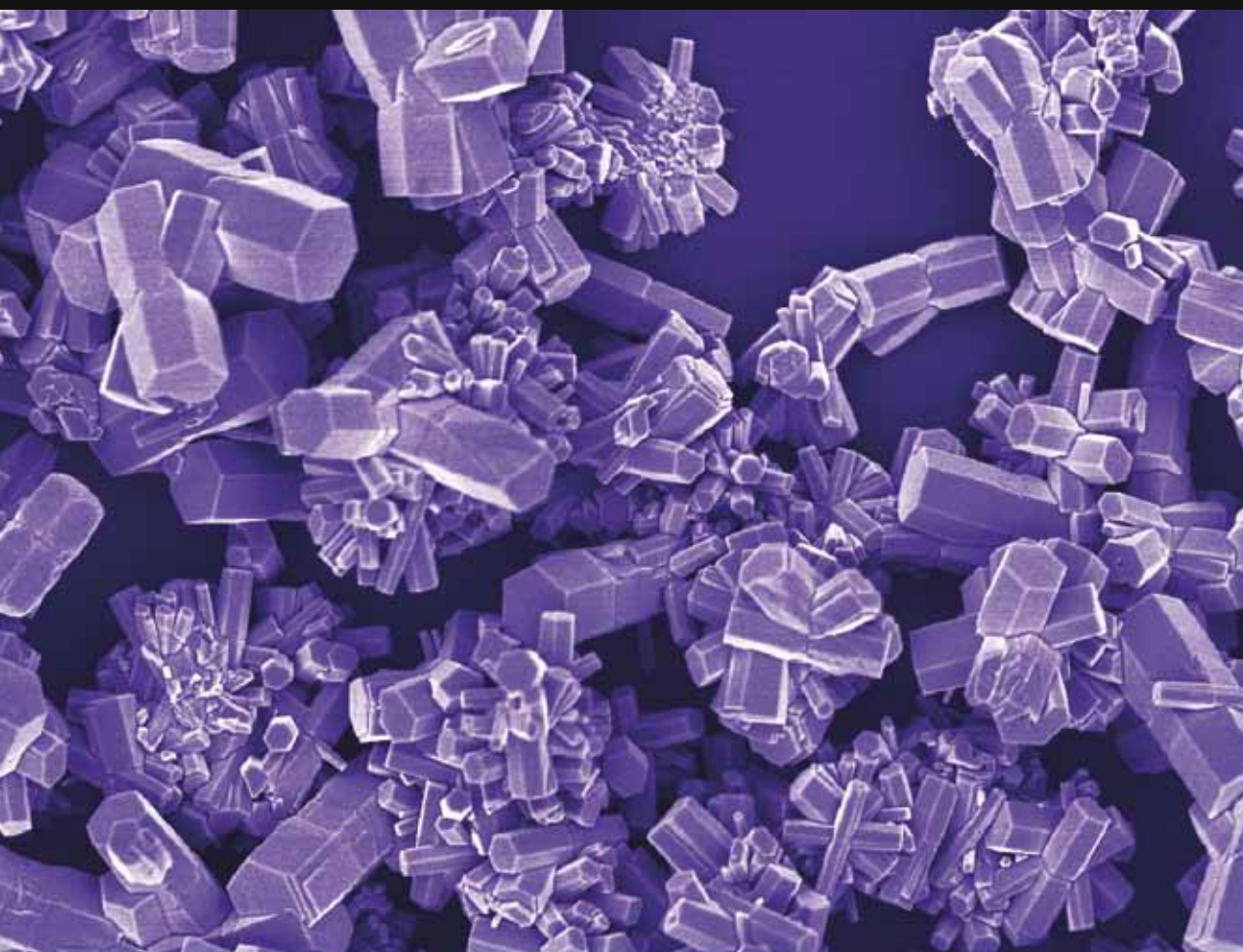
Pearl in the grass

SEM images of tin oxide nanoballs and nanowires
- fabricated by the thermal annealing method.



Quadrate Mars

Zinc oxide nanoparticles patterned in an approximately square shape on a silicon substrate. The nanoparticles are synthesized by simply evaporating the zinc oxide powders at high temperatures.



SEI 5.0kV x3,300 1µm WD 6mm

Stones

Stone-shape zinc oxide nanoparticles on a silicon substrate. The nanoparticles are synthesized by simply evaporating the zinc oxide powders at high temperatures.

FURTHER READING

Huang, H., Mao, S., Feick, H., Yan, H., Wu, Y., Kind, H., Weber, E., Russo, R., Yang, P. (2001) Room-temperature ultraviolet nanowire nanolasers. *Science*, 292, 5523, 1897 – 1899.

Lau, S.P., Yang, H.Y., Yu, S.F., Li, H.D., Tanemura, M., Tanaka, J., Okita, T., Hng, H.H. (2005) Laser action in ZnO nanoneedles selectively grown on Si and plastic substrates. *Appl. Phys. Lett.* 87, 013104.

Lau, S.P., Yang, H.Y., Yu, S.F., Yuen, C., Leong, E.S.P., Li, H.D., Hng, H.H. (2005) Optically pumped flexible UV random laser. *Small*, 1, 956-959.

Yang, H.Y., Lau, S.P., Yu, S.F., Tanemura, M., Okita, T., Hatano, H., Teng, K.S., Wilks, S.P. (2006) Wavelength-tunable and high-temperature lasing in ZnMgO nanoneedles. *Appl. Phys. Lett.* 89, 081107.

Yang, H.Y., Lau, S.P., Yu, S.F., Abiyasa, A.P., Tanemura, M., Okita, T., Hatano, H. (2006) High-temperature ZnO nanoneedle random lasers. *Appl. Phys. Lett.* 89, 011103.

Yang, H.Y., Lau, S.P., Yu, S.F., Huang, L., Tanemura, M., Tanaka, J., Okita, T., Hng, H.H. (2005) Field emission from zinc oxide nanoneedles on plastic substrates. *Nanotechnology*, 16, 1300-1303.

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Huiying leads a research group in nanoscience and nanotechnology at Nanyang Technological University in Singapore. The group focuses on studying nanomaterials and their unique electrical and optical properties and applications in photonics science and biomedical science.

Huiying was attracted by the beauty of the nano-world and enjoys inventing and discovering unknowns. She has extensive research experience in the following: applications of high-resolution transmission electron microscopy; nano-probe electron energy-loss spectroscopy and energy dispersive X-ray spectroscopy for quantitative structure determination of the crystals and interfaces of nanostructures; synthesis and characterization of nanostructures and thin oxide films; promoting low-threshold and high-efficiency nano-light emitting devices on plastic substrates and nanostructures based bio-sensors.



Huiying has published over 50 research papers in academic journals. In 2005, she first reported about ZnO nanoparticles based inorganic flexible UV lasers in the journal *Small*. She then went on to demonstrate low-threshold ZnO nanoneedles lasing on Si and plastic substrates, published in *Applied Physics Letters*. The ZnO nanolasers on plastic substrate, which can be manipulated, or made to bend as flexible nanolasers, created great interest in the nano-optics world, and was selected as one of the top 12 inventions in the 5th Young Inventors Awards. Huiying's paper on wavelength-tunable nanolasers was one of the most cited papers in *Applied Physics Letters* in 2006.

Huiying won first prize in *Nanoscience-as-Art Competition* in NTU during her PhD program. Her research on Nano-material also created some interesting artwork, which won second prize in the Materials Research Society (MRS) "Science as Art" competition. Huiying was awarded the *Chinese Government Award for Outstanding Self-Financed Students Abroad 2005* in February 2006 and was interviewed for the Discovery Channel in February 2009. Huiying was awarded the prestigious *Lee Kuan Yew Postdoctoral Fellowship* in August 2008 which will support her research, providing both a stipend and research grant.

Huiying says: "In my experience, the golden rule of research is: 'Create with inspiration, innovate with perspiration'. I will continue to conduct my work in this nano world and work hard to bring new ideas and innovations to economically and environmental-friendly optical and electrical nano-devices."