FUTURE PAVEMENT TECHNOLOGY
NANOTECHNOLOY

WARRIP
WESTERN AUSTRALIAN ROAD RESEARCH & INNOVATION PROGRAM

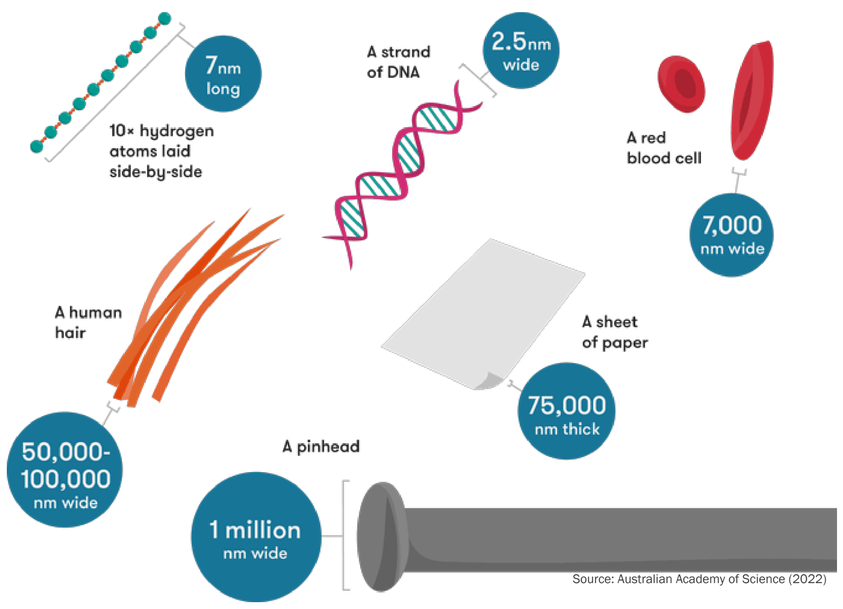
Identifying opportunities for innovative applications of nanotechnology to improve engineering material properties.

Nanotechnology

The design, production and application of structures, devices and systems at the nanoscale. Nanosized particles have been developed and utilised to manipulate the engineering properties of materials.

Nanoscale Size

The prefix “nano” means one-billionth or 10^{-9} of a meter. As such, the nanoscale is the dimensional range of 1—100 nm or 10^{-9} –10^{-7} m. Relative size examples measured in nanoscale:

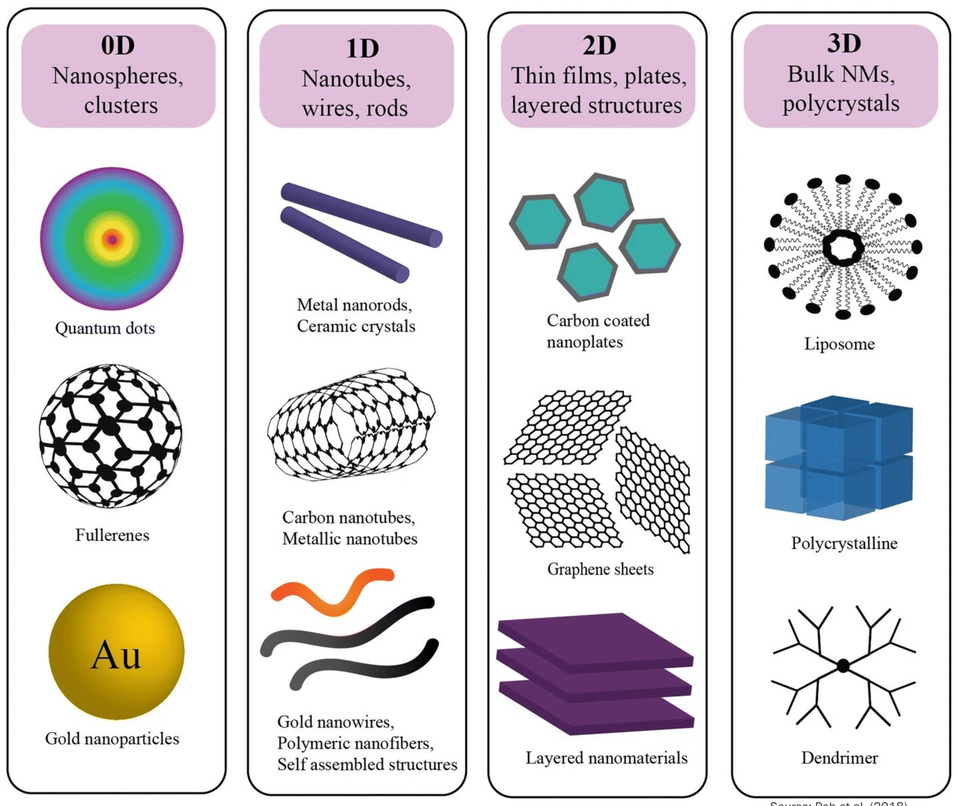


Source: Australian Academy of Science (2022)

Nanomaterial Classification

Nanomaterials can be inorganic, organic or biological. Some materials such as nanoplates, nanowire etc. can be engineered in labs. Nanomaterials can also occur in nature—such as minerals, soils, biogenic particles etc.

Nanomaterials exist in different dimensionality and the current classification scheme of nano-structured materials are proposed.



Source: Poh et al. (2018)

Pavement Applications

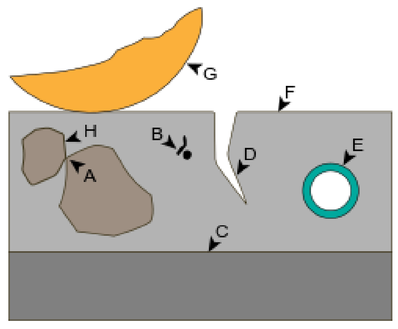
In pavement engineering, nanotechnology applications include:

- Sustainable and perpetual asphalt pavements, minimizing the usage of natural resources and increasing durability (Maher et a;. 2006).
- Air purifying pavements with titanium dioxide (TiO_2) (Murata et al. 1998).
- Self-sensing concrete pavement with piezoresistive multi-walled carbon nanotubes for traffic monitoring (Han & Ou 2007).
- Luminescent concrete pavements for safe road by nanophosphors (Steyn 2008).

Asphalt Pavement Applications

In asphalt pavements, promising areas for nanotechnology applications include:

a. Intra stone properties (shear, tension)
b. Mastic properties (stiffening, cohesion, durability, workability)
c. Bond between layers (tack coats)
d. Self-repair (healing/rejuvenating agents)
e. Binder film oxidation, binder segregation
f. Surface properties (friction, optical properties, water repellent, abrasion resistant, surface protection (i.e. Self-cleaning seal coats))
g. Anti-adhesion surface for construction machinery
h. Bond adhesion between stone and the mastic

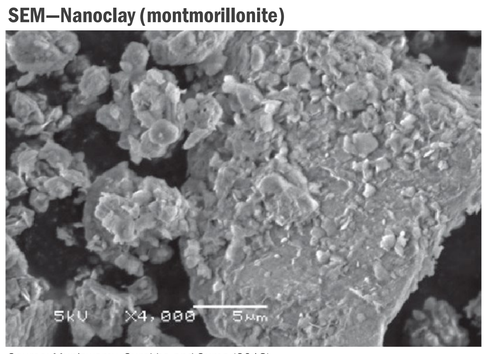


Bitumen is a viscoelastic material that exhibits both viscous and elastic properties, or a combination of both, depending on the temperature and loading rate.

Multiple nanomaterials (e.g. carbon nanotubes, silica, alumina, magnesium, calcium, iron oxide, TiO2) have been incorporated into bituminous binders to modify and improve their engineering properties . Nanoclays and Nanosilica materials are more suitable for asphalt mixes.

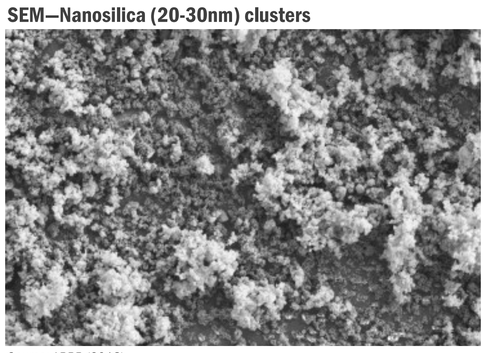
Research has demonstrated that small quantities (1-6% by mass) of nanoclays and Nanosilica added to bitumen binders have positively affected the performance such as rutting, fatigue, aging and storage stability.

SEM—Nanoclay (montmorillonite)



Source: Muniswamy, Surekha and Suma (2018)

SEM—Nanosilica (20-30nm) clusters



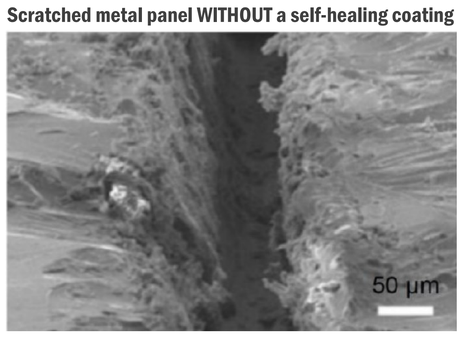
Source: ARRB (2018)

Concrete Applications

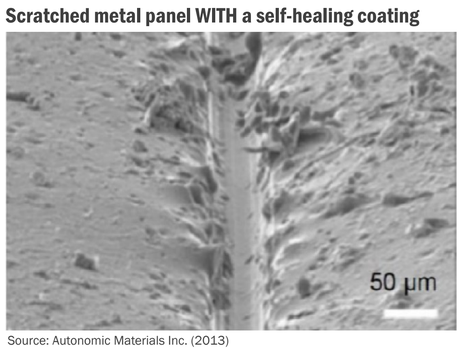
Nanomaterial applications in concrete can generate a material with self-sensing, self-cleaning and/or self-healing characteristics. Concrete with self-healing capacities have the potential to seal micro-cracks, this preventing micro-crack propagation. Promising areas for nanotechnology applications in concrete include:

- Self-healing materials
- Crack-preventative materials
- Self-cleaning materials
- Shape alloy (SMA) materials

Scratched metal panel WITHOUT a self-healing coating



Scratched metal panel WITH a self-healing coating



Source: Autonomic Materials Inc. (2013)

What further research opportunities are there in this space?

Investigate the effects of nano-clay modified binders on asphalt mix performance.

The role of self-healing agents in enhancing the properties and performance of concrete pavements or structure.