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Neutron scattering of interpenetrating polymer networks (IPNs) as medical devices

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A common material for urinary catheters is a hydrophobic polymer, silicone elastomer. The properties of silicone make it well-suited for producing medical devices; it has favourable mechanical properties and is chemically inert. However, this hydrophobic surface makes it prone to the adhesion of bacteria and subsequent and rapid formation of biofilms. The bacteria that grow in biofilms tend to be resistant to antibiotic treatment, and device-associated infections present a real challenge in modern medicine. To reduce the adhesion of bacteria and the risk of infection, the Danish company BioModics produces silicone catheters and medical devices that are functionalised by the inclusion of a hydrophilic hydrogel interpenetrating polymer network (IPN), which is introduced using supercritical carbon dioxide. This expands the silicone, and then hydrophilic monomers are introduced to react and form an IPN within the silicone network. This hydrogel not only reduces the risk of infection, but it is also has the potential to act as a drug delivery mechanism. The IPN acts as a reservoir for hydrophilic small molecules that can be suspended and then controllably released at site from the IPN-impregnated silicone.

The release properties are dependent on the morphology of the IPN. However, it is a challenge to get insights to the hierarchical structure of the IPNs. As part of Denmark's LINX Project (Linking Industry to Neutrons and X-rays), our team at the Niels Bohr Institute (University of Copenhagen, Denmark) performs neutron and X-ray scattering measurements on industrially-relevant materials working in conjunction with industry partners.

A successful SINE2020 proposal was essential to determine the feasibility of using neutron scattering to obtain useful structural information about the IPN. We had already performed preliminary X-ray scattering measurements in the Niels Bohr Institute, but these only revealed the structure of the inorganic filler in the silicone and gave no information about the structure of the IPN component. In the SINE2020 experiments, samples of IPN were submerged in heavy water (D2O), which partitioned into the hydrophilic hydrogel and gave sufficient neutron scattering intensity to study the structure. Both small-angle neutron scattering (SANS) and spin-echo small-angle neutron scattering (SESANS) measurements were provided, covering a size range from ~1 nanometre to ~3.5 micrometre, which was important for a hierarchical structure such as these IPNs.

These SINE2020 measurements have inspired further SANS and SESANS studies into more series of IPNs with different silicones and different concentrations and different hydrogels. I will describe how we initially assessed these materials using our in-house equipment (in the Niels Bohr Institute) and then by neutron scattering (via SINE2020) and have continued this since. I will then discuss these nanostructured materials as promising future medical devices and how the structure-property relationships arising from scattering measurements are assisting optimisation of the materials for the future.

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