Carbon-ceramic nanofibrous membranes with hierarchical structure CF-CNF-SiC for drinking water purification

Access to clean water is one of the greatest challenges facing humanity in the 21st century. Pollution caused by industrialization, population growth, and climate change threatens water resources worldwide. Traditional water treatment methods are often insufficient, especially when it comes to removing biological contaminants such as bacteria and biofilms that form on filtration membranes. These biofilms not only reduce the efficiency of filtration systems but also increase energy consumption and maintenance costs.

This research project aims to develop a new generation of filtration membranes that combine the unique properties of carbon nanofibers (CNF) and silicon carbide (SiC) ceramics. The innovative approach involves creating hierarchical membranes—materials with a carefully designed structure at both the micro and nanoscale. These membranes are engineered to resist the growth and attachment of microorganisms, significantly reducing the problem of biofouling, which is one of the main obstacles to long-term, efficient water purification.

The core of the project is the use of electrospun carbon nanofibers, derived from polyacrylonitrile (PAN), which are further modified with SiC precursors. Two types of SiC sources are employed: synthetic (polysiloxane) and natural (rice husk), the latter representing a sustainable use of agricultural waste. By combining carbon and ceramic phases, the resulting membranes exhibit exceptional mechanical strength, chemical and thermal stability, and, most importantly, antibacterial and antifouling properties.

A key advantage of these new materials is their environmental safety. Unlike other carbon nanomaterials such as carbon nanotubes or graphene, CNFs are less toxic and more stable, minimizing the risk of secondary pollution. The addition of SiC further enhances the durability of the membranes, making them suitable for use in harsh conditions, such as high temperatures or aggressive chemical environments.

The research plan includes optimizing the manufacturing process for these composite membranes, thoroughly analyzing their structure and properties, and testing their effectiveness in real-world water filtration scenarios. Special attention is given to their ability to prevent the formation of bacterial biofilms and to their overall environmental impact.

The expected outcome of the project is the creation of advanced filtration membranes that are not only highly effective at removing biological contaminants but also durable and environmentally friendly. This innovative solution addresses the urgent need for reliable, safe, and sustainable water purification technologies, contributing to global efforts to ensure access to clean water for all.