functional nanoparticles from Cellulose

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Scientists from CSIR National Chemical Laboratory (CSIR-NCL), Pune have recently synthesized spherical shaped nanoparticles from agricultural residue. These nanoparticles showed antimicrobial activity and can also be used for drug delivery. The uniqueness regarding this research is that obtained nanoparticles have spherical shapes and a very narrow size distribution (25-32 nm). These nanoparticles can prove as a potent tool in nanotechnology.

Nanoparticles are very important tool in biology and medicine. They have various applications in biomedical science such as bioimaging and drug delivery.

Cellulose is the most abundant, annually renewable, and extremely versatile polymer with various applications. Conversion of cellulose to nanocellulose has led to many new high end applications.

The application of the nanoparticles can often be controlled by engineering their shape, size and surface functionality. The researchers from CSIR-NCL have successfully synthesized the nanoparticles having spherical shape, a very uniform range of size and with carboxy groups on the surface. Surface functionalisation of nanoparticles is an effective way to control the interface between nanoparticles surface and the biological systems they are designed to interact with. Scientists from Germany in similar study have recently synthesized aminofunctional cellulose nanoparticles having the size distribution in the range 80-200 nm.

Carboxycelluloses are used in wound dressing gauzes, surgical materials, and several other related biomedical products for over 70 years. Hence this area has attracted many researchers. The spherical shaped nanoparticles of carboxycelluloses can have significantly improved properties as compared to their currently available analogs. Hence, the CSIR-NCL team decided to investigate methods to prepare spherical nanoparticles of carboxycelllose.

The scientists have illustrated for the first time a very simple method to obtain spherical shaped polymer nanoparticle. Previously, obtaining spherical shaped nanoparticle was a complicated task requiring very specific conditions such as ten hours sonication in acidic condition involving, high temperature, mechanical stirring, centrifugation, washing with distilled water etc. The CSIR-NCL procedure produced nanoparticles in high yield, and required only 15 min ultrasonication to produce stable aqueous dispersion of nanoparticles.

A team lead by Dr. A.J. Varma, Chief Scientist and Head, Polymer Science and Engineering Division has utilised easily available low molecular weight agricultural residue derived cellulose as well as higher molecular weight cotton cellulose to prepare 6-carboxycellulose nanoparticles (6-CCNP). Hence this can be one of the methods of agricultural residue management. It is after 15 years from first report of longitudinal carboxy

functional cellulose nanofibrils that CSIR-NCL scientists have reported spherical carboxy functional cellulose nanoparticles

The nanoparticles synthesized by the research team are found to have enhanced antimicrobial activity against microorganism Escherichia Coli as well as many other bacterial species, as compared to their larger sized analogs. This has opened up a further research area for biomedical applications for 6-CC nanoparticles.

Priyanka Sharma, co-author of the research program said that the spherical shape of the particle is expected to prove to be a very effective tool in drug delivery and many new applications. Spherical shape provides greater surface area as well as spherical nanoparticles are more stable in aqueous suspension than nanofibers. As cellulose is a rigid backbone polymer, so far only longitudinal nanofibrils could be prepared.

The CSIR-NCL team has demonstrated one more phenomenon for the first time with the nanoparticles that the functionalised nanoparticles are extremely efficient in the stabilisation of carbon nanotubes with minimal ultrasonication, hence saving energy. The carbon nanotubes are cylindrical nanostructures of carbon which are very valuable in nanotechnology, electronics and optics. It is very difficult to stabilise the aqueous solution of the carbon nanotubes for the reaction

purpose. However, with the help of synthesized 6-CCNP researchers could achieve highly stable dispersions of both single-walled and multi-walled carbon nanotubes for several days.

Fluorescent 6-CCNP can potentially be used in bioimaging. Cellulose nanomaterial substrates have also been investigated for use in the fabrication of recyclable organic solar cells. Further development in this field by use of 6-CCNP can lead to their increasing use in energy production technologies.

The synthesis of such kind of functional nanoparticles has opened up various areas for research and its applications. These include biomedical applications, photoswitchable titanium dioxide nanocellulose aerogels, flexible magnetic nanopaper for electronic applications, and so on.

CSIR-NCL has already taken provisional patents on synthesis as well as some novel applications for this compound. Work on applications development and eventual commercialisation in collaboration with Indian industries is being explored.

Cellulose:

1838 : Structure of cellulose found,

1949 : the first longitudinal nanofibre reported,

2007 : the first quasi-spherical nanoparticle of cellulose in 2007 (after 58 years; that too of over 100 nm size)

Carboxy functionalised cellulose

(Biomedically important polymer):

1883 : first synthesized

1940s : first commercialised

1998 : first longitudinal nanofibre reported

2013 : first report of spherical nanoparticle in 2013 (this CSIR-NCL work, 15 years after the longitudinal nanofibre was reported).

Further reading: Functional nanoparticles from cellulose: engineering the shape and size of 6-carboxycellulose, Priyanka R Sharma and Anjani J Varma, Chem Commun, 2013, 49, 8818-8820