Borregaard

DISPERSION OF CARBON NANOTUBES WITH

VANISPERSE LI

The new organic additive for lithium-ion batteries

VANISPERSE® LI

Borregaard's bio-based battery additives are designed for use in water-based electrode slurries and to stabilize aqueous carbon nanotube (CNT) dispersions. Obtained from sustainably sourced wood, our products are non-toxic, environmentally friendly, and highly effective. Vanisperse LI provides a uniquely sustainable alternative and affords a lower CO2 footprint than petroleum-derived additives. Efficient dispersion of CNTs is critical for achieving uniform electrode composition and optimal battery performance. Sustainable water-soluble dispersants are essential to de-agglomerate CNTs in water, preventing the hydrophobic carbons from reforming agglomerates.

What is Vanisperse LI? Vanisperse LI is an effective dispersant for a wide range of carbon materials in Li-ion battery electrodes, including conductive carbons and CNTs. Derived from Norway spruce, it is a modified sodium ligno-sulfonate that works by adsorbing onto the active material and providing steric and electrostatic stabilization.

What challenges are associated with dispersing CNTs in water? There are two main challenges: (1) physical interlocking or entanglement among CNTs, and (2) CNTs in water tend to agglomerate due to strong hydrophobic interactions.

The left image in Fig. 1 shows CNTs in their supplied dry form, which are already heavily agglomerated. When these agglomerated CNTs are placed in water, they gradually form larger clusters despite being stirred or sonicated as shown in Fig.1, right.

How does Vanisperse LI address the challenge of dispersing CNTs in water? The problem is addressed by dissolving Vanisperse LI in water containing CNTs, which prevents carbon-to-carbon interactions. This results in a stable dispersion of individual CNTs, effectively preventing re-agglomeration.

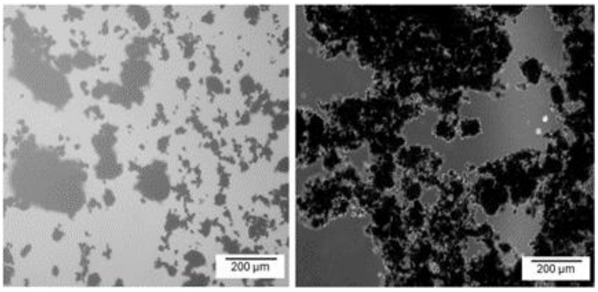

Figure 1: Left image, Agglomerated CNTs as supplied. Right image, Re-agglomerated CNTs in water after intense sonication, illustrating the reformation of aggregates post-dispersion without Vanisperse LI, regardless of the intensity of mechanical mixing/sonication.

When physical CNT interlocking is significant, sufficient mechanical mixing is also crucial.

What dosages of Vanisperse LI should be used? The required Vanisperse LI dosage for optimal dispersion will depend on type of carbon, with one of the most significant factors being the carbon's surface area. We recommend starting with a dosage of 1 mg of Vanisperse LI per square meter of total carbon surface area in the system. For some very high surface area carbon materials, like CNTs, this may require a Vanisperse LI:CNT ratio as high as 1:1.

How is the effectiveness of Vanisperse LI demonstrated when dispersing CNTs? The effectiveness of Vanisperse LI dispersing CNTs can be demonstrated through various methods:

a) Microscopy, (Fig. 2.): The microscopy images show that CNTs without Vanisperse LI form large agglomerates (top-right), whereas those with Vanisperse LI are much finer and more evenly distributed (top-left). This visual evidence underscores the role of Vanisperse LI in preventing carbon-to-carbon interactions and maintaining good dispersion.

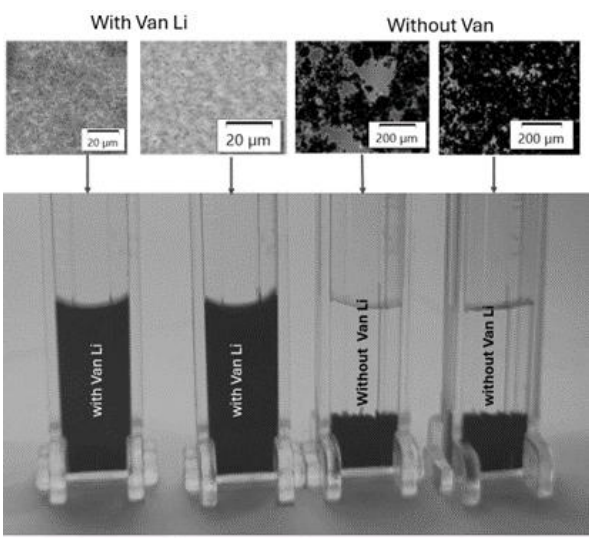

Figure 2: Stability of the suspension over time for two types of CNTs in water with and without Vanisperse LI.

b) Suspension Stability, (bottom Image, Fig. 2.): The sedimentation tests further demonstrate the effectiveness of Vanisperse LI. CNT suspensions without Vanisperse LI (right) sediment rapidly, while those with Vanisperse LI (left) remain stable over time, showing no sedimentation. This indicates that Vanisperse LI effectively stabilizes the suspension by keeping the CNTs dispersed and preventing re-agglomeration.

c) Viscosity Curves, (Fig. 3.): The viscosity curves illustrate the effectiveness of Vanisperse LI. The suspension without Vanisperse LI shows higher viscosity and a significant decrease in viscosity as shear rate increases, indicating the presence of agglomerates that temporarily break down or deform under shear, resulting in shear thinning behaviour. In contrast, the suspension with Vanisperse LI shows a lower and more consistent viscosity, reflecting stable dispersion and de-agglomeration as particle-to-particle interactions under flow are diminished.

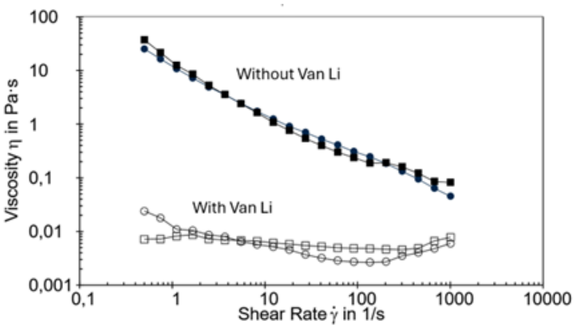

Figure 3: Viscosity as a function of shear rate for two types of CNTs dispersed with and without Vanisperse LI. These are suspensions having 1% of CNTs and 1% of Vanisperse LI in water.

Can CNT suspensions with Vanisperse LI be stored long-term? We have observed that when CNTs are dispersed with Vanisperse LI into individual entities or even small agglomerates (e.g. 100-150 µm in size), they will remain suspended in water over an extended period, as shown in Fig. 2

The extent of the mechanical mixing can determine whether the result is a dispersion of individual CNT entities or small agglomerates.

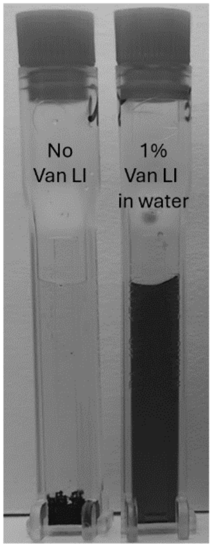

Figure 4: Picture after 3 months of storage. Agglomerated CNTs after mechanical dispersion without Vanisperse LI (left). Small clusters of CNTs, approx. 140 µm in size, dispersed by Vanisperse LI (right).

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