Characteristic Properties of Cellulose Materials Modified by Chitosan

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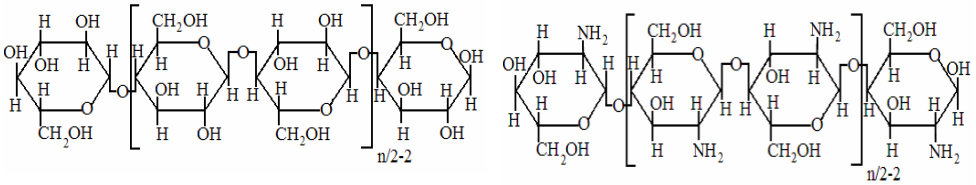
Provided to the important properties of cellulose such as absorbability and impregnability, it is one of the oldest organic dielectric materials that are still in demand in high voltage applications. Dielectric materials derived from renewable resources have the key advantage over materials produced from oil. Their long-term availability does not depend on gradually depleting amount of oil on Earth. Instead, renewable resources can provide a perpetual source of such materials.

Dielectric cellulose materials have certain characteristics that limit their application. One of them is the limited thermal stability. Molecular structure of cellulose decays under operational temperature with time. It does not affect much electrical properties of papers and cardboards but their mechanical properties become worse. In addition to that, cellulose dielectric materials are often used in reeled form, which imposes mechanical overstrain onto the molecular structure of cellulose. This results in formation of active radicals. These active radicals are the substantial contributors to the processes of decay of dielectric materials. They accelerate such decay processes. This brings up the need to improve mechanical strength and thermal stability of cellulose without degradation of its electrical properties.

One of the effective ways to improve properties of cellulose materials is modification of cellulose with chitosan (a derivative of chitin), which has a molecular structure similar to cellulose (Fig. 1). Chitin and chitosan get their niche in different areas of human needs from medicine to rural economy, but there are isolated instances of researches them as dielectrics materials.



Cellulose Chitosan

Figure 1: Molecular structure of cellulose and chitosan

In 1970s, Department of Electrical Insulation of Saint-Petersburg Polytechnic University with co-authors developed a method of production of dielectric papers and cardboards with chitosan. This method was applied with to decrease the loss of aluminum oxide.

However, it was found that chitosan not only affects the resulting quantity of aluminum oxide but it also affects mechanical and electrical properties of cellulose material. Two sets of cellulose paper were researched. They were modified with chitosan that was introduced into cellulose foundation in different ways. Set #1 included cellulose paper with 1% and 5% of chitosan by mass. Chitosan was introduced via impregnation with a solution in 1% acetic acid. Set #2 had from 1% to 3% of chitosan by mass. This set was produced by grinding and pressing a dry mixture of the two polymers.

Tests show (Table 1) that introduction of chitosan has very little effect on the dielectric loss coefficient (tgδ) of modified material in comparison to pure cellulose paper. At the same time, it increases short-term breakdown strength (Ebr) and tensile strength (σUTS).

Table 1: Electrical and mechanical properties of cellulose paper modified with chitosan (f=50Hz)

Set	#1			#2	
	Pure cellulose	Cellulose + 1% Chitosan	Cellulose + 5% Chitosan	Pure cellulose	Cellulose +(1-3)% Chitosan
(tgδ±Δtgδ)100°C	0.0013±0.0001	0,0013±0.0001	0.0014±0.0001	0.0014±0.0001	0.0014±0.0001
(Ebr ± ΔE), kV/mm	8.5 ± 0.3	9.1 ± 0.2	9.7 ± 0.3	9.1 ± 0.3	11.7 ± 0.3
(σUTS±Δσ U), MPa	79 ± 2.5	83 ± 2.3	90 ± 2.5	90 ± 2.7	118 ± 3.2

Our hypothesis is that due to molecular structure similarity of polysaccharides and strong NH2-groups of chitosan, macromolecules of biopolymer bond cellulose foundation. Highly active NH2-groups of chitosan interact with OH-groups of cellulose and strengthen cellulose foundation (Fig. 2). We also observed the relation between breakdown and tensile strength and the way how cellulose was modified. Thus, set #1 shows an increase of breakdown strength by 7% to 14% and tensile strength by 5% to 14%. Set #2 indicates the increases of 28% and 30%, correspondingly.

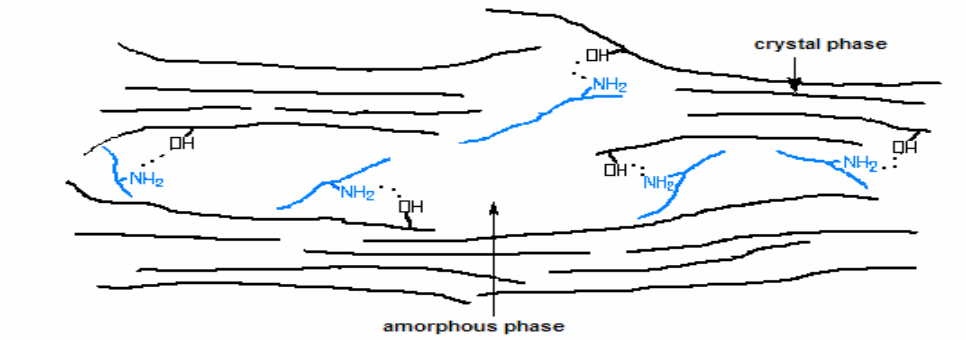


Figure 2. Scheme of modification cellulose foundation with macromolecules chitosan (NH2-groups).

Results of our research indicate that chitosan can improve different properties of cellulose materials without any significant negative impact.