STUDY OF NANO-PLASTICS CONTAINING FILLERS OF VARIOUS TYPES

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1. INTRODUCTION

Nano-technology is advanced and quickly developed field of material engineering. This technology operates with objects having sizes from below one up to thousand nanometers. Main fields of nano-technology application are material engineering, life sciences, microelectronics and other areas. One from the most developed fields of the nano-technology is nano-composites and especially nano-plastics containing polymer binders and inorganic nano-fillers, such as clay, silica, chalk, titanium dioxide, ceramics, etc. However, the inorganic nano-fillers have the following disadvantages:

- High density increases weight of composites and articles
- High abrasibility decreases life time of an equipment
- High hardness hinders polishing of coatings
- Low bonding ability with organic polymers hinders strength rising
- Bio-stability hinders production biodegradable plastics
- Settling ability in liquid systems causes to their heterogeneity

In contrast with inorganic, organic fillers can contain various functional groups allowing them bonded with an organic polymer that leads to strength rising of the plastics. Moreover, organic fillers have low density, hardness and abrasibility and increased stability to settling in liquid systems, such as paints, varnishes, coatings, etc. Besides, organic fillers made from natural polymers are biodegradable.

However, nano-plastics and other polymer nano-composites based on organic nano-fillers were studied insufficiently. Therefore, aim of this investigation is to prepare polymer nano-composites containing both organic and inorganic nano-fillers and to study properties of these composites.

2. MATERIALS AND METHODS

To manufacture the polymer nano-composites the following polymers were used: Polyvinylchloride (PVC), Polyethylene (LDPE), Polycaprolactone (PCL) and Poly-styrene-acrylic resin (SAR) in the latex form.

Nano-fillers were prepared from kaolin-clay and bleached wood cellulose by means of technology showing in table 1.

Table 1. Technology for preparation of the nano-fillers

Stages	**Nano-cellulose**	**Nano-clay**
1	Chemical depolymerization	Wet grinding
2	Water dispersion treatment in a high pressure homogenizer	Water dispersion treatment in a high pressure homogenizer
3	Centrifugal concentrating	Centrifugal concentrating
4	Ultrasonic disintegration	Ultrasonic disintegration
5	Freeze drying	Freeze drying
6	Vortex super-fine milling	Vortex super-fine milling

As a result, the nano-fillers having average particle size in the range 300 - 500 nm were prepared (Fig. 1). Other characteristics of the nano-powders can be seeing from table 2.

Table 2. Main characteristics of the nano-fillers

Characteristics	**Nano-cellulose**	**Nano-clay**
Average particle size, nm	500	300
Specific weight, g/cm^3	1.5-1.6	2.6-2.7
Bulk density, kg/m^3	200-250	350-400
Specific surface, m^2/g (Water Vapor BET- Method)	100-120	20-40
Biodegradability, % per month	100	0

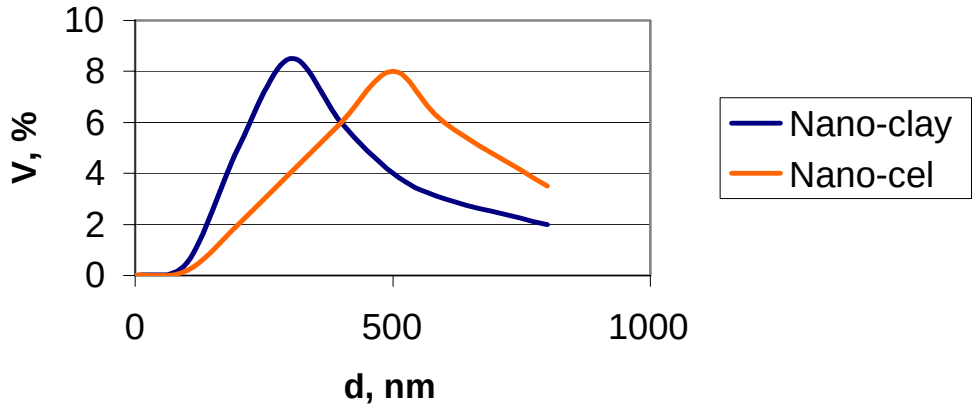
The organic cellulose nano-powder has lower specific weight and more developed specific surface than inorganic clay nano-powder. Moreover, the cellulose based organic powder able to biodegradation, while clay based nano-filler is biostable.

The nano-plastics in a form of thin plates were manufactured by means of an extrusion technology. The following characteristics of the nano-plastics were studied:

- Tensile strength - **TS**, Mpa (**ASTM D 638)**
- Permeability - **P**, cm^3cm/cm^2s Pa (**Polymer Handbook, N.Y. , 1989; ASTM E 96**)
- Heat conductivity - **HC**, $kWs^{1/2}/m^2grad$ (**ASTM D 5930**)
- Biodegradation - **BD**, % per months (**ASTM D 2020, D 5988; BSI BS 6085**)

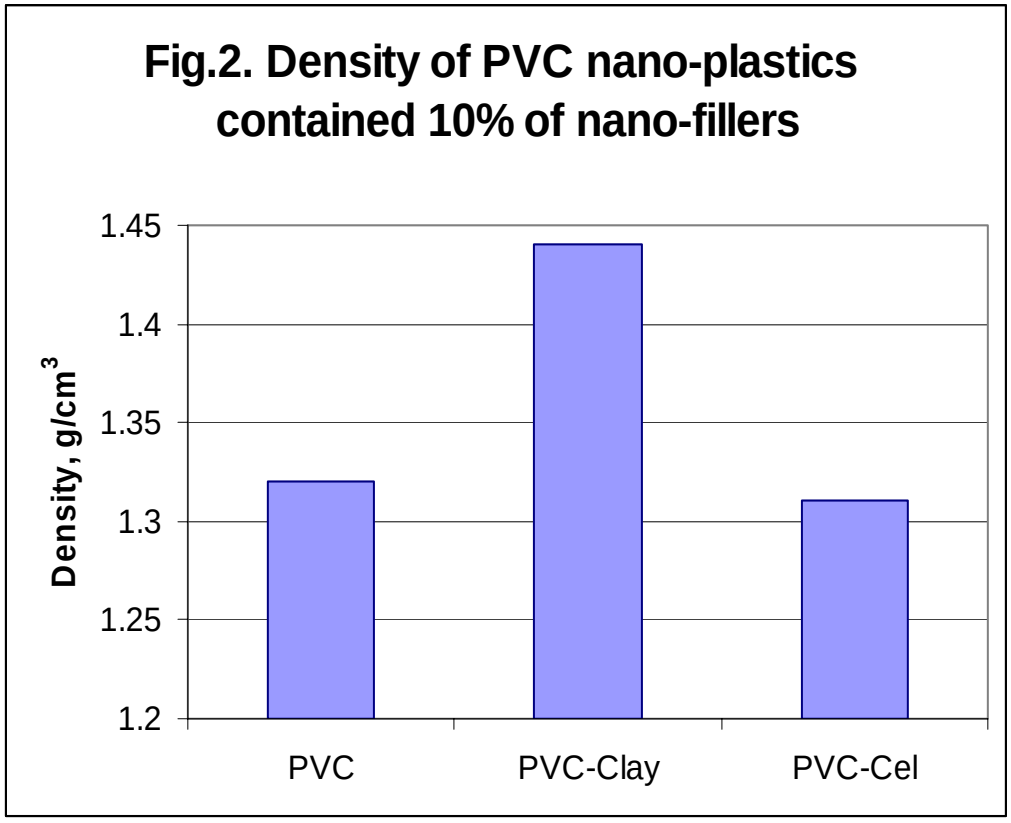
Besides, SAR-based emulsion paint compositions containing TiO_2-pigment, GCC-co-pigment, nano-extenders and medium were prepared. Paint coatings were applied on to opacity charts of Sheen Instruments using the 100 microns bar applicator. Opacity value (contrast ratio) of the dry paint coating was measured by Sheen Opac Reflectometer.

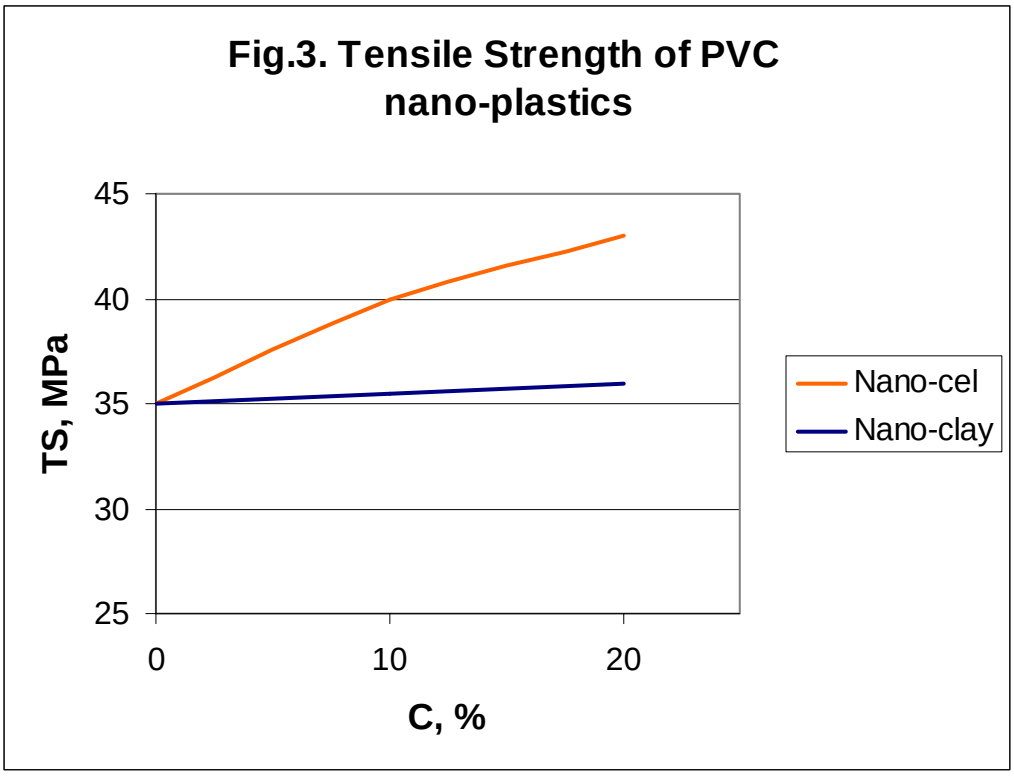
Fig.1. Particle size distribution
(Mastersizer 2000)



3. RESULTS

Difference in characteristics of the organic and inorganic nano-fillers (Table 2) influences directly on properties of the nano-plastics. All plastics contained the nano-cellulose are lighter, but stronger than plastics filled with nano-clay powder. This can be illustrated with physical-mechanical properties of the PVC nano-plastics (Fig. 2, 3).





The weight-light organic nano-filler doesn't change PVC-plastics density, but increases their strength due to compatibility between the polar organic nano-filler having developed specific surface and the polar polymer binder. In contrast to organic, the heaver inorganic nano-filler leads to increasing in density of the PVC-plastics. However, it affects weak on the plastic strength, because this filler not contains polar functional groups.

Organic nano-cellulose filler imparts to plastics heat-insulating properties, while inorganic nano-clay raises heat-conductivity of the nano-plastics (Fig. 4).

Peculiarity of the nano-cellulose filler is its selective water vapor permeation (Fig. 5). This property can be useful in manufacturing artificial leathers. On the other hand, the nano-fillers improve barrier properties of some polymers against transmission of gases that is important for the polymer packaging (Fig. 6).

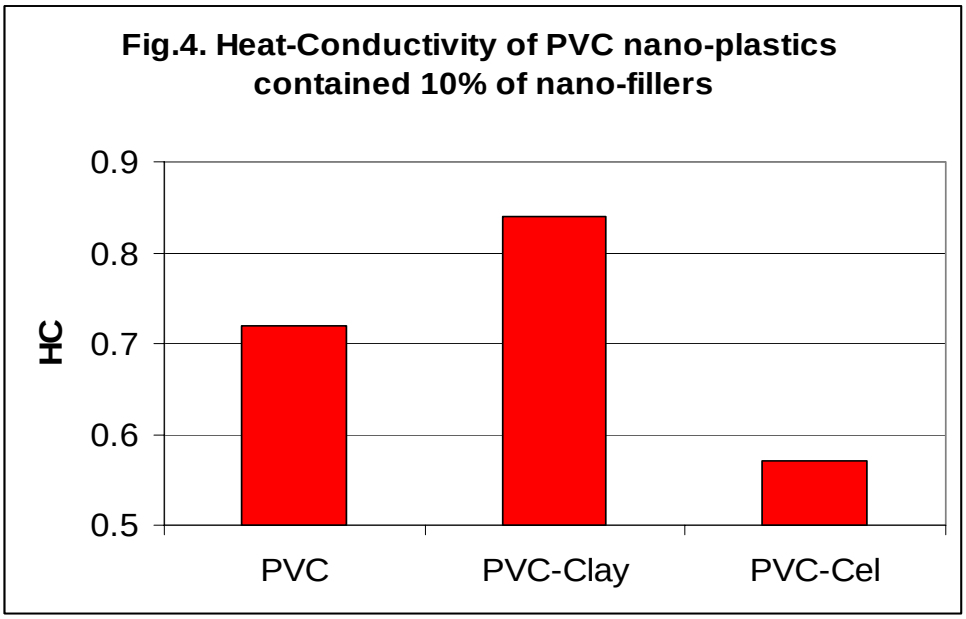


Fig.4. Heat-Conductivity of PVC nano-plastics contained 10% of nano-fillers
0.9
0.8
0.7
0.6
0.5
HC
PVC
PVC-Clay
PVC-Cel

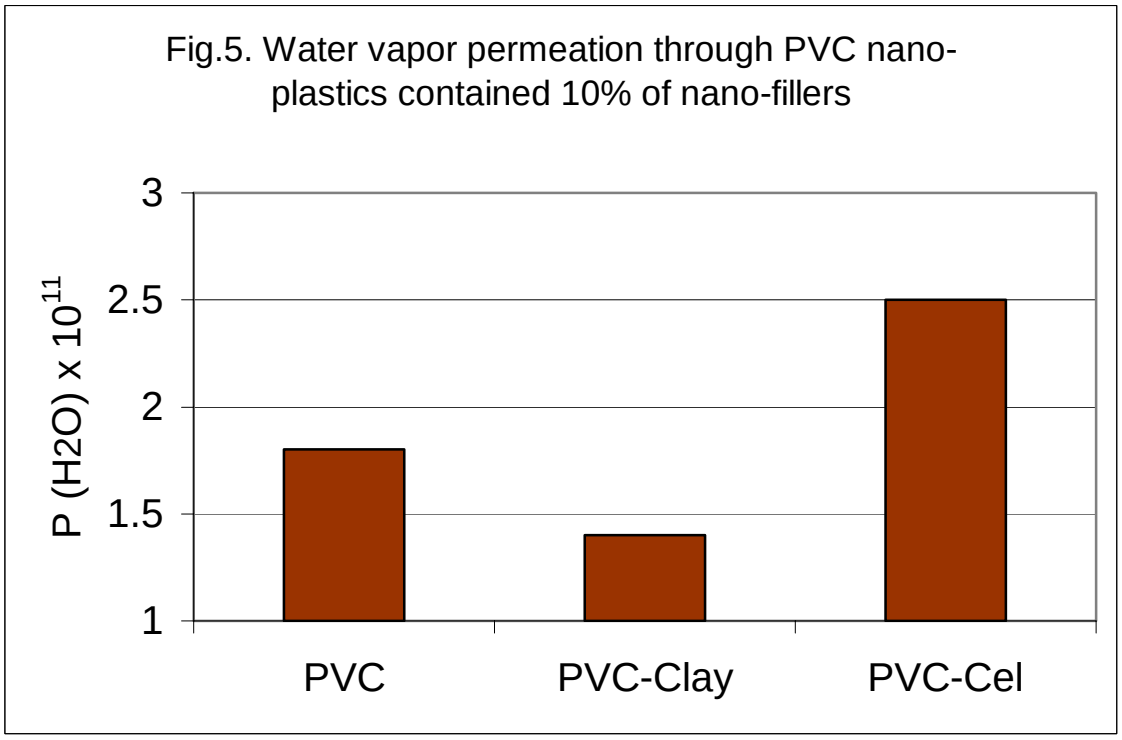
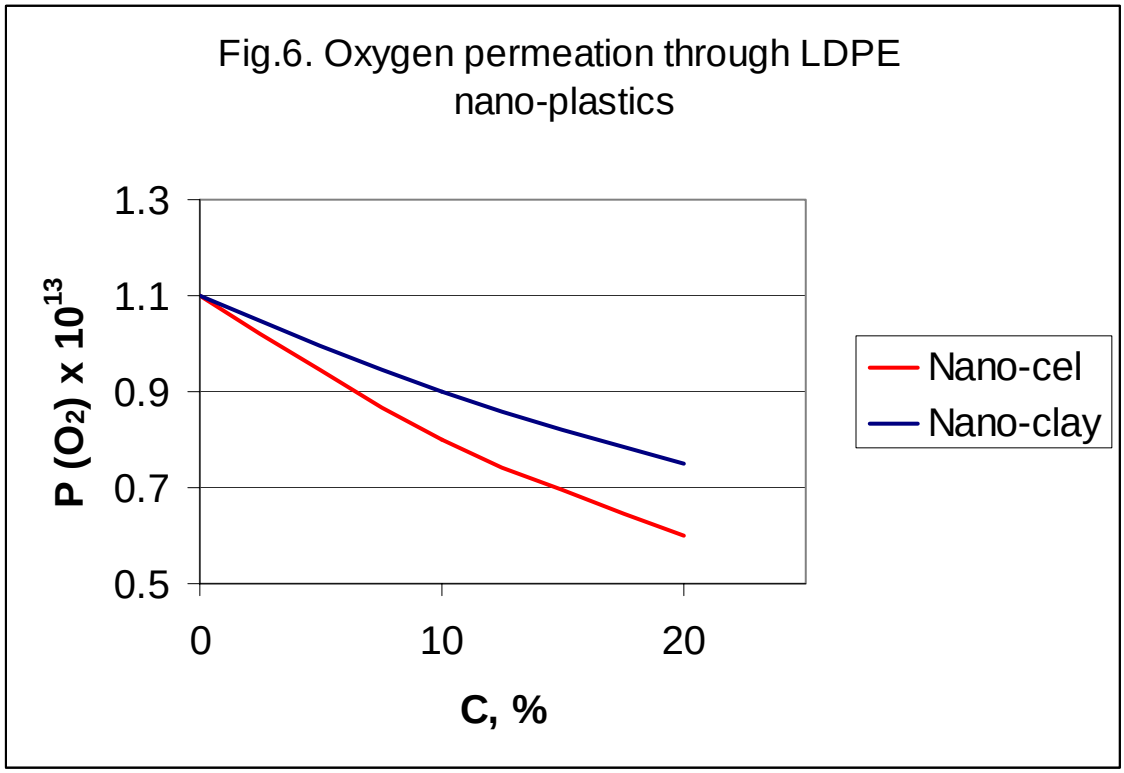


Fig.5. Water vapor permeation through PVC nano-plastics contained 10% of nano-fillers
3
2.5
2
1.5
1
P (H2O) x 10^11
PVC
PVC-Clay
PVC-Cel



Filling of biodegradable polymers with the nano-cellulose promotes their bio-decomposition ability, while the inorganic nano-filler hinders bio-decomposition of these polymers (Fig. 7).

Nano-powders show excellent extender properties for emulsion paints and coatings contained mineral pigments. Introduction a low amount of the nano-extenders into SAR-based paint compositions permits replacing a significant amount of TiO_2-pigment without changing in paint opacity value (Table 3). However, due to lower specific weight and better compatibility with organic polymer binder nano-cellulose is more effective extender than nano-clay.

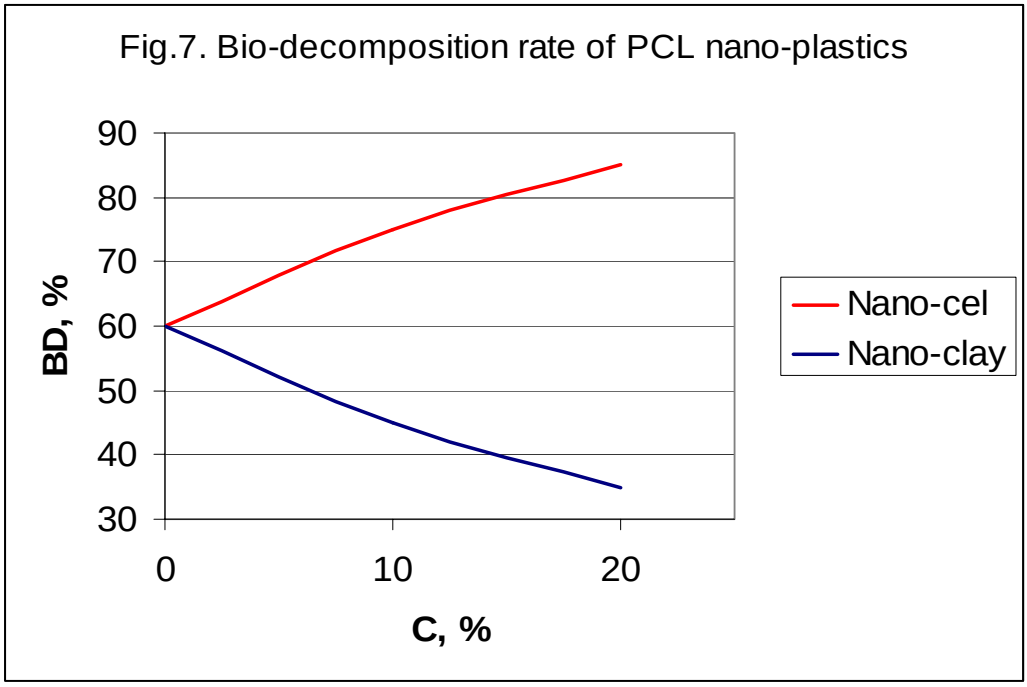


Table 3. Characteristics of interior paint compositions based on SAR-binder (Pigment volume concentration = 60%)

Components	**Composition, %**		
	No 1	**No 2**	**No 3**
TiO_2	20	13	16
GCC	30	30	30
Nano-extenders: Nano-cel Nano-clay	 0 0	 3 0	 0 3
SAR-binder	25	26	26
Medium	25	28	25
Characteristics			
TiO_2-Saving, %	0	35	20
Opacity value	0.94	0.95	0.94

4. CONCLUSION

So, the organic nano-filler imparts to plastics some peculiar properties, such as light-weight, increased strength, reduced hot-conductivity, selective water permeation, barrier against oxygen transmission and raised biodegradability. Moreover, this nano-filler improves properties of polymer based emulsion paints and coatings. Wide application of the organic nano-fillers can create new nano-materials having unique characteristics and properties.