CRITICAL INDEX OF COMPOSITE POLYMER MATERIALS CONTAINING NICKEL NANOPARTICLES

O'ktamova N.B. [1]
Boymuratov F.T. [2]
[1] 2nd year student of the Faculty of Medicine, Alfraganus University, Tashkent, specializing in therapeutic work, nuktamova@mail.ru , +998992362644
[2] Associate Professor, Department of Pharmacy and Chemistry, Faculty of Medicine, Alfraganus University, Tashkent. f.boymuratov@afu.uz , +98909277694,
https://doi.org/10.5281/zenodo.17066483

В данной работе определен критический индекс электропроводности композиционных полимерных материалов, содержащих нано и высокодисперсные частицы никеля. Показано, что бесконечный кластер в композитах, содержащих наночастицы никеля более извилистей по сравнению композитов, содержащие высокодисперсные частицы Ni.

Ключевые слова: теплопроводность, проводимость ,критический индекс, полимерных материалов, наночастицы никеля.

In given working is determined critical index to conduction composition polymeric material, containing nano and the high-dispersed nickel particles. It is Shown that infinite cluster in composites containing, nanoparticles of the nickel more sinuous by comparison - in the high-dispersed of the particles.

Key words: conductivity, semiconductor pyro-polymer, composite polymeric materials, nanodispersed, heterogeneous systems, nicel.

The nature of the dependence of electrical conductivity (σ) polymer composites from the concentration of conductive filler (V_1) can be described by formulas obtained within the framework of percolation theory [1-3]. According to percolation theory [4], conductivity σ systems containing metal particles randomly distributed in a dielectric matrix are described by the following formulas:

$$\sigma(V_1) = \sigma_1 \left(\frac{V_1 - V_c}{1 - V_c}\right)^t, \qquad V_1 \geq V_c, \qquad (1)$$

$$\sigma(V_1) = \sigma_2 \left(\frac{V_c - V_1}{V_c}\right)^{-q}, \qquad V_1 < V_c, \qquad (2)$$

Where σ_1 - conductivity of metal particles; σ_2 -conductivity of the dielectric matrix; V_c -the critical concentration (percolation threshold) at which an infinite cluster of filler particles is formed for the first time; t and q are parameters called critical indices, the values of which for three-dimensional systems are 1.6 and 0.98, respectively. When an infinite cluster of metal particles is tortuous, the calculated values $t>1.6$ [5]. However, this conclusion has not been experimentally proven. The present work is devoted to this issue.

Two types of composites were prepared for the studies. One is a metal-polymer composite containing nanosized nickel particles. The other is a metal-polymer composite containing highly dispersed nickel particles. In both cases, phenylone was used as a polymer matrix.

A composite with nickel nanoparticles was prepared by thermal decomposition of nickel formate in phenylone. The following procedure was used. Nickel formate powder was added to phenylone, phenylone dissolved in dimethylformamide in a proportion of 4 g of phenylone per 100 g of solvent. After thorough mixing, the resulting mixture was heated to evaporate the solvent. During evaporation, in order to prevent aggregation of nickel formate powder particles, the mixture was treated with ultrasound at a frequency of 22 kHz and a power of 0.3 W, using a UZDN-1 disperser. The mixture formed as a result of solvent evaporation was placed in a vacuum and maintained at a temperature of 373 K for 1 hour to remove residual solvent. After that, the temperature was raised to 573 K, and the mixture was maintained at this temperature for 5 hours until complete decomposition of nickel formate. In the resulting composite, the size of nickel particles did not exceed 30 nm, as determined by small-angle X-ray diffraction. The composite with finely dispersed nickel particles was prepared by mixing nickel powder with phenylone in an agate mill for 7 hours. The nickel powder used was prepared by thermal decomposition of nickel formate in vacuum at 573 K for 3 hours. In this powder, the particle sizes of nickel were in the range of 1 to 3 μm, as determined by a BS242E electron microscope.

In both cases, the desired nickel content is V_1 in the prepared composites was obtained by calculating the initial materials used. To perform electrical measurements, samples were prepared in the form of tablets with a diameter of 15 mm and a thickness of 2 mm by hot pressing.

The figure shows the experimental dependences of the conductivity σ on the fractional Ni content for both composite materials under study. This figure also shows the dependences σ from V_1 calculated within the framework of percolation theory, using the above formulas (1) and (2). For the composite materials under study, the critical fractional volume V_c nickel particles was determined by differentiation $\lg\sigma$ by V_1. To determine the critical index t, the experimental data were presented as a graph in coordinates lgσ-lg[(V_1-V_c)/(l-V_c)]. The value t is the slope of this graph. The values σ_1 and σ_2 were obtained by extrapolating this graph to V_1=1 and V_1=0 respectively. It was found that V_c = 0.105 and t = 2.20 for composite material with nanosized nickel particles and V_c= 0.210 and t = 1.78 for a composite material with highly dispersed nickel particles. The critical index q was taken to be equal to 1, which is true for three-dimensional systems [4]. As can be seen from the figure, for both types of composite materials under study, the correspondence between theoretical and experimental data is observed at $V_1>V_C$. In case $V_1<V_C$ correspondence between theoretical and experimental dependences is observed only for a composite material with highly dispersed nickel particles. The origin of this discrepancy can be understood within the framework of the spatial-structural hierarchical model recently proposed by Balberg et al. for composite materials [6].

Methods of percolation theory allow us to establish the topology of the resistance network of an infinite cluster [4,5]. One of the characteristics of heterogeneous inhomogeneous systems is the density of an infinite cluster P(V_1). Near the leak threshold P(V_1) has the form [5].

$P(V_1) = D\,(V_1 - V_c)^{\beta}$.

where D is a numerical coefficient of order one, β - critical index, for three-dimensional systems, equal to 0.4. The value P(V_1) characterizes the proportion of nodes belonging to an infinite cluster $V_1 < V_c$ size $P(V_1) \equiv 0$ because there is no infinite cluster. With increasing V_1 meaning P(V_1) increases, when V_1 =1 P (V_1) must also be equal to one.

To determine the length of the skeleton of an infinite cluster, we use the model first proposed by B.I. Shklovsky. For a plane problem, this model [4] is something like a very large fishing net. The characteristic linear size of a cell of this net is called the correlation radius and is expressed by the formula R= L / ($\frac{V_1 - V_c}{1 - V_c}$)$^{-\nu}$, where L is the length equal in order of magnitude to the lattice period, ν - critical index of the correlation radius (in the three-dimensional case ν = 0,8).Based on this model, it is shown that if the wire forming the skeleton has tortuosity, then Z, the length of the wire between the intersection points, is greater than R and is expressed by the formula

$$Z = L\left(\frac{V_1 - V_c}{1 - V_c}\right)^{-\xi},$$

Where ξ- critical index. Value

$$\frac{Z}{R} = \left(\frac{V_1 - V_c}{1 - V_c}\right)^{-(\xi - \nu)} \qquad (3)$$

shows how many times the length of the skeleton is greater than R due to tortuosity. Critical indices t, ξ and ν are related to each other by the ratio ξ=t-ν [5].

As can be seen from the table, the value $P(V_1)$ when moving away from the flow threshold towards larger ones V_1, increases. This means that the infinite cluster gradually joins finite clusters formed between nickel particles, becoming more and more "dense". At t = 1.6, the value of R is equal to Z, i.e. there is no tortuosity of the infinite cluster. The values $\frac{Z}{R}$, calculated by formula (3) at t = 1.78 and t = 2.20 are given in the table. As can be seen from the table, near the percolation threshold in composites containing nickel nanoparticles, the infinite cluster is more tortuous, compared to composites containing highly dispersed particles. These results show that the higher the dispersion, the more tortuous the infinite cluster in such composites.

Table

Dependence of parameters $P(V_1)$ and $\frac{Z}{R}$ from the volume fraction of the filler V_1.

V_1	$P(V_1)$	$\frac{Z}{R}$ at t =1,78	$\frac{Z}{R}$ at t =2,20
0,13	0,25	1,8	8,7
0,16	0,34	1,6	5,4
0,20	0,41	1,4	3,9
0,23	0,46	1,4	3,4
0,3	0,54	1,3	2,5
0,4	0,64	1,2	1,9
0,4	0,68	1,1	1,8
0,5	0,72	1,1	1,6

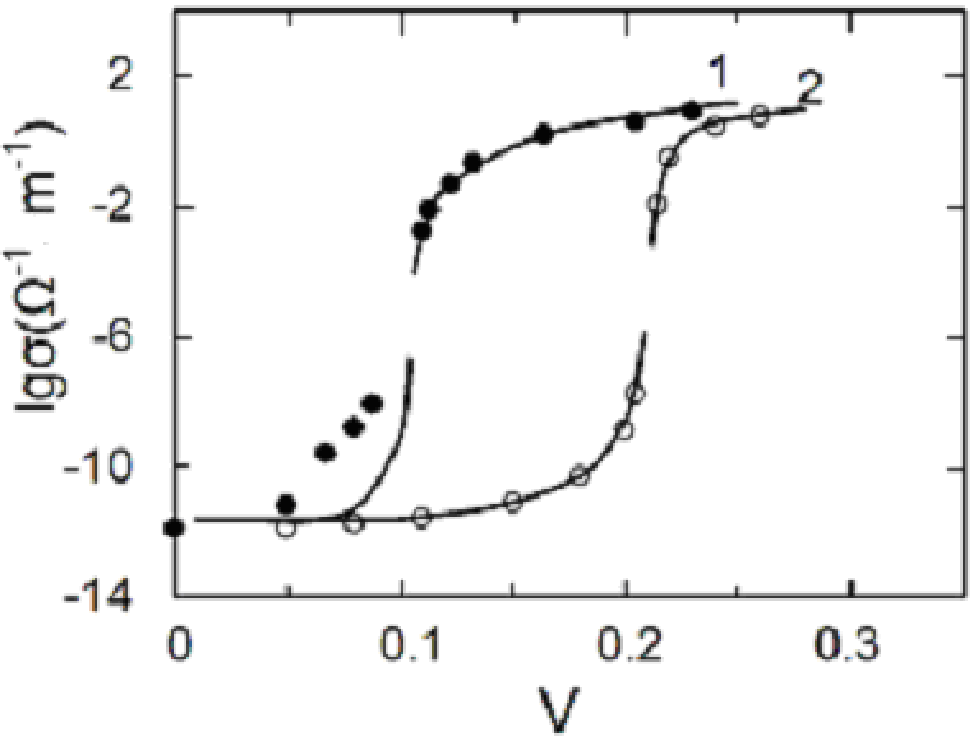

Figure 1. Comparison of experimental (dots) and calculated (curves) dependence of electroconductivity on the content of nickel and polymer composites with nanosized (black dots, curve 1) and highly dispersed (empty dots, curve 2) components.

Reference List:

1. Абдурахманов У., Зайнутдинов А.Х., Камилов Ш.Х., Магрупов М.А. // Высокомолек. соед. А. 1988. Т.30. №6.С. 1234-1238.

2. Возняковский, А. П., Неверовская, А. Ю., Отвалко, Ж. А., Возняковский, А. А., & Шугалей, И. В. (2023). Композиционные материалы на основе эпоксидных олигомеров и графеновых нанопластин как основа защитных покрытий с улучшенным комплексом экологических параметров. Экологическая химия, (32 (1)), 19.

3. Islamov, B. K., Mamaeva, D. A., & Vakhobov, K. I. (2023). Solid phase dissolution fibroin of natural silk. The American Journal of Engineering and Technology, 5(01), 1-6.

4. Хорольская, С. В., Полянский, Л. Н., Кравченко, Т. А., Конев, Д. В., & Крысанов, В. А. (2015). Эффект перколяции в динамике редокс-сорбции кислорода металл-ионообменными нанокомпозитами. Российские нанотехнологии, 10(9-10), 73-77.

5. ИСЛАМОВ, Б., & ТАШПУЛАТОВ, С. (2024). РАЗРАБОТКА СПОСОБОВ ПОЛУЧЕНИЯ ВОЛОКНОСОДЕРЖАЩИХ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ НА ОСНОВЕ ВТОРИЧНОЙ ПЕРЕРАБОТКИ ОТХОДОВ.

6. Balberg I., Azulay D., Toker D and Millo O. // Int. J. Mod. Phys. 2004. B. V. 18, P.2091- 21

7. Абдураимов, Д. Э. Ў., Норматова, М. Н., & Монасипова, Р. Ф. (2021). ЛИБМАН ТИПИДАГИ ИТЕРАЦИН УСУЛНИ ЭЛАСТИКЛИК НАЗАРИЯСИ МАСАЛАСИГА ҚЎЛЛАШНИНГ МАТЕМАТИК МОДЕЛИ. Science and Education, 2(1), 15-20.

8. Халджигитов, А. А., Каландаров, А. А., & Абдураимов, Д. Э. (2020). Численное решение динамической краевой задачи теории упругости для ортотропных тел. Инновацион ва замонавий ахборот технологияларини таълим, фан ва бошқарув соҳаларида қўллаш истиқболлари халқаро конференцияси материаллари, 548-551.

9. Seytov, A., Abdurakhmanov, O., Kakhkhorov, A., Karimov, D., & Abduraimov, D. (2024). Modeling of two-dimensional unsteady water of movement in open channels. In E3S Web of Conferences (Vol. 486, p. 01023). EDP Sciences.

10. Нафасов, Г. А., & Абдураимов, Д. Э. ТРАНСВЕРСАЛ ИЗОТРОП ЖИСМ УЧУН ИККИ УЛЧОВЛИ ТЕРМОЭЛАСТИК БОГЛЩ МАСАЛАНИ СОНЛИ МОДЕЛЛАШТИРИШ ВА УНИНГ ДАСТУРИЙ ТАЪМИНОТИ. КарДУ ХАБ, 13.