New hybrid materials based on cyclophosphazene and polysiloxane precursors: synthesis and properties

Khanin D.A.,[1] Kononevich Yu.N.,[1] Temnikov M.N.,[1] Morgalyuk V.P.,[1] Vasil'ev V.G.,[1] Popov A.Yu.[1], Brel V.K.,[1] Papkov V.S.,[1] Muzafarov A.M.[1,2]

[1] *A.N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, 119991 Moscow, Russian Federation,*

[2] *N.S. Enikolopov Institute of Synthetic Polymeric Materials, Russian Academy of Sciences,117393 Moscow, Russian Federation.*

Abstract

New cross-linked polymers with different morphology based on cyclotriphosphazene and polysiloxane precursors were obtained by the thiol-ene radical addition. A series of samples such as aerogels with various density, a xerogel, a monolith and a film were prepared and their physico-mechanical properties were studied. Phosphazene-containing polymeric aerogels were prepared directly in supercritical carbon dioxide ($scCO_2$) media. The morphology of the samples was investigated by scanning electron microscopy (SEM). The average particle size in the aerogels was in the range of 2-15 μm. The mechanical properties of all the samples were studied by the compression test. It was shown that the Young modulus of the monolith (95 MPa) was 7 times larger than that of the xerogel (14 MPa). The aerogels are porous elastic polymers with the Young modulus of 0.032 and 0.257 MPa, correspondingly. The thermal stability of the samples was evaluated by thermal gravimetric analysis (TGA). Weight loss was observed in the range of 255-298 °C in air and 251-295 °C in argon for all the samples. Aerogel samples have a greater water contact angle (130° for **A1** and 136° for **A2**) than xerogel (122°), monolith (121°) and film samples (84°), which can be explained by the lotus effect.

Keywords

Hybrid materials; phosphazene; siloxane; aerogel; xerogel.

Conclusions

In summary, new hybrid materials with different morphology such as aerogels, xerogel, monolith and film were obtained based on organoelement precursors, cyclotriphosphazene and polysiloxane, by the hydrothiolation reaction and their physico-mechanical properties were studied. It was shown that varying the conditions for the formation of the mesh structure allows one to prepare polymers with specified mechanical characteristics. Studies of the morphology of the samples by scanning electron microscopy (SEM) showed that the average particle size was in the range of 2-15 μm in the case of aerogels. The mechanical properties of all the samples were studied by the compression test. It was shown that the Young modulus of the monolith (95 MPa) was 7 times larger than that of the xerogel (14 MPa) whereas aerogels **A1**, **A2** are porous elastic polymers with the Young modulus of 0.032 and 0.257 MPa correspondingly. The thermal stability of the samples was estimated by thermal gravimetric analysis (TGA) which showed a good thermal stability of these materials. Weight loss was observed in the range of 255-298 °C in air and 251-295 °C in argon for all the samples. The aerogel samples have a greater water contact angle (130° for **A1** and 136° for **A2**) than the xerogel (122°), monolith (121°) and film samples (84°), which can be explained by the lotus effect.

Acknowledgment

This work was supported by the Russian Foundation for Basic Research (RFBR) (Project No. 18-03-00275 A) and by the Ministry for Science and Higher Education of the Russian Federation, Grant of the Government of the Russian Federation No. 14.W03.31.0018. Electron microscopy characterization was performed at the Department of Structural Studies of Zelinsky Institute of Organic Chemistry, Moscow. The characterization of the compounds obtained was performed with financial support from Ministry of Science and Higher Education of the Russian Federation using the equipment of Center for molecular composition studies of INEOS RAS (IR and NMR spectroscopy). Analysis of water contact angles was performed using the equipment of the Collaborative Access Center "Center for Polymer Research" of ISPM RAS.

References

[1] M. Faustini, L. Nicole, E. Ruiz-Hitzky, C. Sanchez, History of Organic-Inorganic Hybrid Materials: Prehistory, Art, Science, and Advanced Applications, Adv. Funct. Mater. 28 (2018) 1704158. doi:10.1002/adfm.201704158.

[2] S.H. Mir, L.A. Nagahara, T. Thundat, P. Mokarian-Tabari, H. Furukawa, A. Khosla, Review—Organic-Inorganic Hybrid Functional Materials: An Integrated Platform for Applied Technologies, J. Electrochem. Soc. 165 (2018) B3137–B3156. doi:10.1149/2.0191808jes.