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Study of Nano-Al_2O_3 + Nano-SiO_2 + H_2O System by Fourier-IR-Spectroscopy Method

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Abstract

The radiation-thermal decomposition of water in the nano-Al_2O_3+nano-SiO_2+H_2O system in the temperature range (T=373÷673K) under the influence of γ-rays using Fourier transform IR spectroscopy has been studied. Intermediate-active products of radiation-heterogeneous decomposition of water such as aluminum and silicon hydrides, hydroxyl groups have been registered. It was determined that in this heterosystem, an absorption dose of 10 kGy occurs in the radiation-chemical decomposition of water.

Keywords: Radiation; Nanooxides; Fourier-IR Spectroscopy; Radiation-Heterogeneous Processes; Radiation-Thermal Decomposition

Introduction

The development of nanomaterials production is determined by important issues of modern materials science. The transition to nanoscale materials, on the one hand, leads to a reduction in existing dimensions, on the other hand, to a significant increase in the surface area of the nanoparticle system. Thus, when considering processes involving nanoparticles, two factors at the same time - small size and large values of the specific surface - play an important role. Nanooxides (ZrO_2, SiO_2, TiO_2, Al_2O_3, etc.) are currently used as catalysts in the formation of molecular hydrogen during the radiolysis of water under the influence of gamma quanta [1-4]. The most promising catalysts among such nanooxides are aluminum and silicon oxides. These nanoxides are considered selective catalysts for radiation-hetero-gene processes. In the process of radiolysis of water, various methods are used to determine the mechanism of radiation-catalytic action of oxide catalysts, as well as spectroscopic methods [4-7]. Radiation-thermal decomposition of water in many nanooxide + water systems has been studied using Fourier-IR spectroscopy [8-10]. However, there is almost no information in the literature on the radiation-thermal decomposition of water in the nano-Al_2O_3 + nano-SiO_2 + H_2O system. The results of Fourier-IR spectroscopic studies of radiation-thermal decomposition of water at different temperatures on the surface of the nano-Al_2O_3 + nano-SiO_2 + H_2O heterosystem are presented in the presented work.

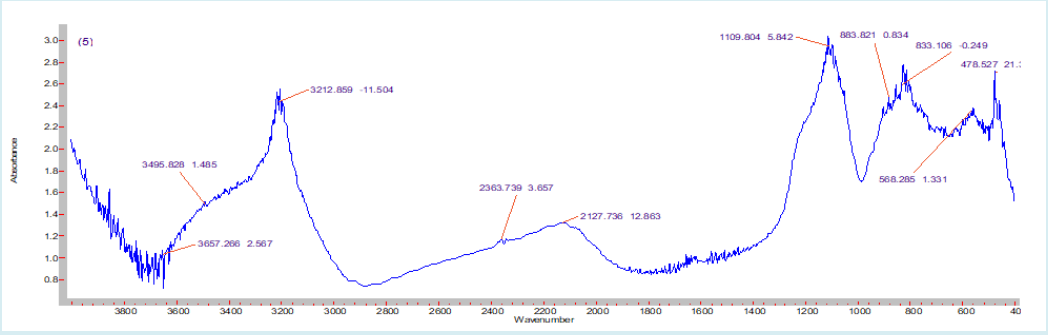
Experimental Part

Al_2O_3 and SiO_2 (Sky Spring Nanomaterials, USA) nanoparticles with dimensions d = 20-30 and 20-60 nm and 99.9% purity were used in the research. After adsorption, aluminum and silicon oxides were subjected to thermovacuum treatment at T = 673K and P = 10^{-3}Pa for 8 hours to clean the surface from organic contaminants. Water adsorption was carried out by the method [6]. Fourier-IR spectra were recorded on the Varian 640FT-IR spectrometer in the range 4000-400cm^{-1}. For this purpose, samples with a

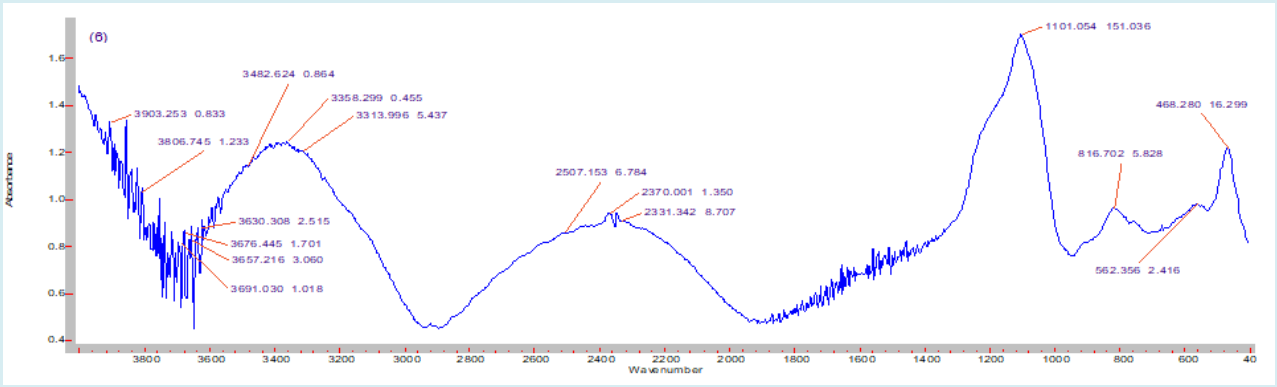
thickness of 0.6-1.2 microns were prepared from Al_2O_3 and SiO_2 nanooxides. Radiation-thermal decomposition of water was carried out in nano-Al_2O_3 + nano-SiO_2 + H_2O system at different temperatures. The samples were irradiated at a dose rate of dD_γ / dt = 0.11 Gy/ s at a ^{60}Co isotope source. Source dosimetry was performed with ferrosulfate and methane dosimeters [11]. The radiation absorption dose in the studied systems was compared with the electron densities. Radiation time was τ = 25 hours (D_γ = 10kGy).

Discussion of Results

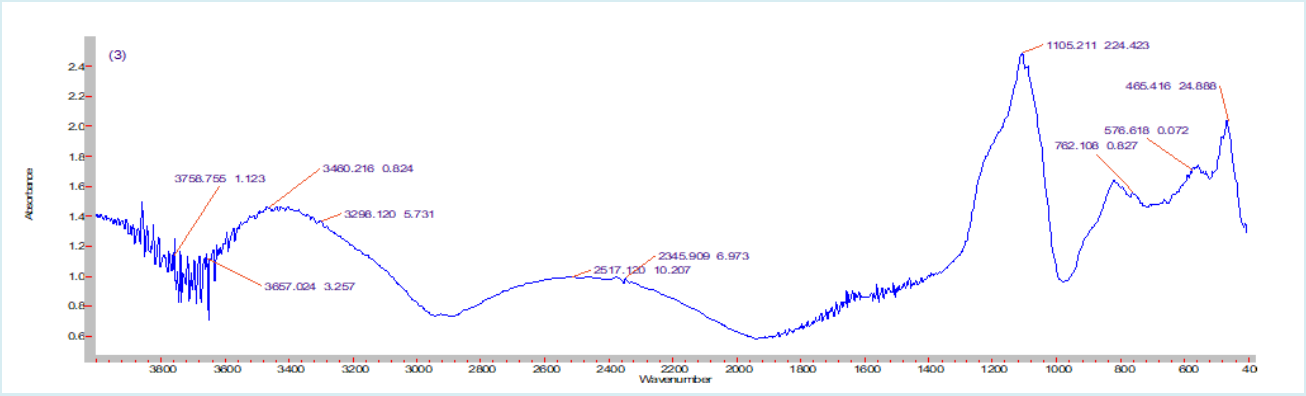
Fourier-IR spectroscopic studies of the nano-Al_2O_3 + nano-SiO_2 + H_2O (1: 1) system were conducted to reveal the interaction between the components of nanooxide (nano-Al_2O_3 and nano-SiO_2), as well as the mechanism of adsorption and radiation-heterogeneous processes. Figure 1 shows the Fourier-IR spectra of the nano-Al_2O_3 + nano-SiO_2 system at different temperatures and during irradiation after water adsorption.



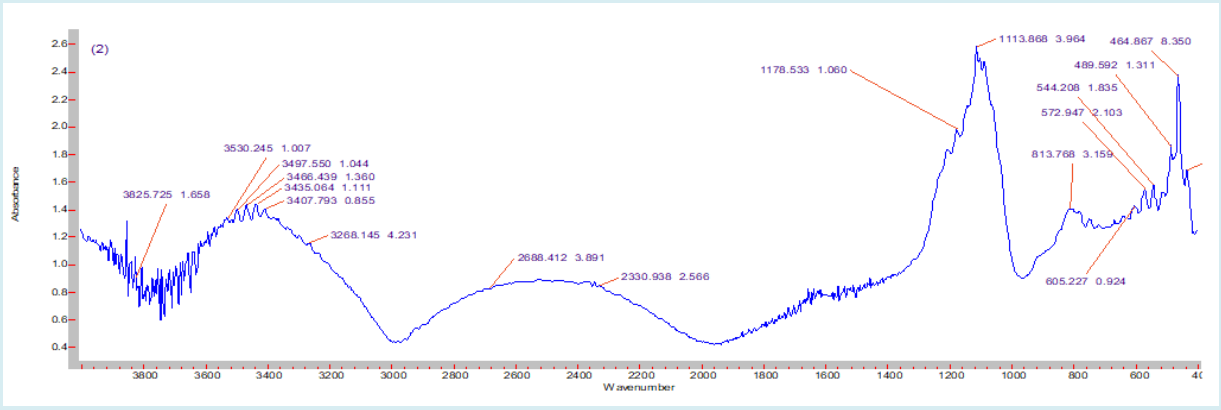
T=373K



T=473K



T=573K



T=673K

Figure 1: Fourier-IR spectra of nano-Al_2O_3 + nano-SiO_2 + H_2O system at different temperatures.

Absorption bands of 3217, 3300, 3495 cm^{-1} maximum hydrogen bonded groups were observed. Increasing the temperature (up to 673 K) in the process of radiation-thermal decomposition of water leads to a decrease in the intensity of hydrogen-bonded absorption bands in the nano-Al_2O_3 + nano-SiO_2 + H_2O heterosystem. At T = 673K, hydrogen-bonded OH-groups and hydrides of nanooxides are completely decomposed. This is due to changes in surface conditions and their defects.

As can be seen from Figure 1, the absorption bands of hydrocarbon-derived contaminants are not observed in the spectra of the heat-treated nanooxide (nano-Al_2O_3 and nano-SiO_2) components [12,13]. Maximum absorption bands 566, 576 and 468, 465 cm^{-1} corresponding to Al-O-Al and Al-O valence oscillations were observed in the spectrum of nano-Al_2O_3 oxide lattice oscillations (ν = 850-400cm^{-1}). As can be seen from the spectra, the maximum peaks of 468, 818, and 1100 cm^{-1} were observed in the region of the lattice oscillations of nano-SiO_2 oxide (ν = 1400-400 cm^{-1}). The observed bands belong to the symmetrical and asymmetric Si-O and Si-O-Si valence oscillations.

Irradiation of the nano-Al_2O_3 + nano-SiO_2 + H_2O system with γ-quanta at a temperature of T = 373K leads to radiation-thermal decomposition of water and the formation of intermediate active products of decomposition. In the heterogeneous system nano-Al_2O_3 + nano-SiO_2 + H_2O, changes in the region of valence oscillations of OH-groups due to radiation-thermal decomposition of water at a temperature of T = 373K are shown in Figure 1.

Conclusion

Radiation-thermal decomposition of water in the nano-Al_2O_3 + nano-SiO_2 + H_2O system in the temperature range T = 373÷673K under the influence of γ-quanta was studied by Fourier-IR spectroscopy. Water adsorption on aluminum and silicon nanooxides occurs by molecular and dissociative mechanisms. Intermediate-active products of radiation-heterogeneous decomposition of water - aluminum and silicon hydrides, hydroxyl groups were recorded. It was determined that in this heterosystem, an absorption dose of 10 kGy occurs in the radiation-chemical decomposition of water. In contrast to the homogeneous phase, radiolysis of water in the presence of aluminum and silicon nanooxides is accompanied by the formation of surface hydrides and hydroxyl groups.

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