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[1]A.V. Dolbin, [1]V.B. Esel'son, [1]V.G. Gavrilko, [1]V.G. Manzhelii,
[1]N.A.Vinnikov, [1]R.M. Basnukaeva,[2] I.I. Yaskovets,
[2]B.A. Danilchenko, [2]I.Yu. Uvarova

[1]B. Verkin Institute for Low Temperature Physics and Engineering of the NASU, 47 Lenin Ave.,
61103 Kharkov, Ukraine, dolbin@ilt.kharkov.ua
[2]Institute of Physics of the NASU, 46 Nauki Ave., 03028 Kiev, Ukraine
*E-mail: danil@iop.kiev.ua

Quantum effects in the kinetics of ^{3}He, ^{4}He, H_2 and D_2sorption by bundles of single-walled carbon nanotubes

The low temperature kinetics of sorption of ^{3}He, ^{4}He, H_2, and D_2 gases by bundles of single-walled carbon nanotubes (SWNT) and the subsequent desorption of these gases from the SWNT bundles has been investigated. The kinetics of gas desorption was investigated on a powder of SWNT bundles compacted into plates under P=1.1 GPa.

Key words: nanotubes, carbon, desorption kinetics.

А.Б. Долбин, В.Б. Ельсон, В.Г. Гаврилко, В.Г. Манжелей,
Н.А. Винников, Р.М. Баснюкаева, И.И. Ясковец, В.А. Данильченко и И.Ю. Уварова

Квантовые эффекты в кинетике ^{3}He, ^{4}He, H_2 И D_2, захваченных пучками одностенных углеродных нанотрубок

Была исследована низкая температура кинетика сорбции ^{3}He, ^{4}He, H_2 и D_2 газов пучками одностенных углеродных нанотрубок (нанотрубок) и последующей десорбции этих газов из нанотрубок пучков. Кинетику десорбции газа исследовали на порошке нанотрубок пучков, запрессованных в пластины под P = 1,1 ГПа.

Ключевые слова: нанотрубки, углерод, десорбция, кинетика

А.Б. Долбин, В.Б. Ельсон, В.Г. Гаврилко, В.Г. Манжелей,
Н.А. Винников, Р.М. Баснюкаева, И.И. Ясковец, В.А. Данильченко, И.Ю. Уварова

Кинетикадағы ^{3}He, ^{4}He, H_2 И D_2 түйінделген бірқабырғалы көміртекті нанотүтікшелердің квантты эффектілері.

Төменгі температурадағы ^{3}He, ^{4}He, H_2 И D_2 түйінделген бірқабырғалы көміртекті нанотүтікшелердің десорбция құбылысы қарастырылды. Газ десорбциясының кинетикасын нанотүтікшелердің ұнтағымен зерттелінді, пластина P = 1,1 ГПа қысымымен престелген.

Түйін сөздер: нанотүтікшелер, көміртек, десорбция, кинетика.

The low temperature kinetics of sorption of ^{3}He, ^{4}He, H_2, and D_2 gases by bundles of single-walled carbon nanotubes (SWNT) and the subsequent desorption of these gases from the SWNT bundles has been investigated. The kinetics of gas desorption was investigated on a powder of SWNT bundles compacted into plates under P=1.1 GPa. The starting powder consisted of closed SWNTs having two basic diameters 1.02-1.06 and 1.69-1.72 nm. The SWNTs in the sample had metallic conductivity. One of the plates of mass 0.07g was heated stepwise to T=500^0 C in dynamic vacuum (~ 10^{-3}Torr) and kept in it for eight hours. This technique allowed us to remove the residual gases from the sample and hence open the ends of the SWNTs. The other plate unaffected by heat pretreatment was irradiated with γ-quanta of ^{60}Co with the dose $1.6\cdot10^7$ rad. The SWNT ends therefore remained closed (c- SWNTs). The irradiation procedure was performed at room temperatures in the H_2 gas medium under the at-

mosphere pressure. This permitted us to increase significantly the rate of radiation defect generation in the SWNTs [1]. The kinetics of gas sorption and desorption was investigated using the technique detailed in [2].

The characteristic times of the sorption-desorption processes coincide within the experimental error. The annealing of the SWNT samples at T=500 C reduced significantly the characteristic times and changed their temperature dependences. The effect of annealing decreased at the molecular weight of the dissolved gas was increasing. The influence of irradiation of SWNT bundles with γ-quanta upon H_2 sorption is qualitatively similar to annealing effect. The lowest activation energy was obtained for He isotopes in o- SWNTs (186 K). It was higher (212 and 224 K) for H_2 and D_2 molecules, respectively. The highest value (E_a=336 K) was measured on c-SWNTs irradiated with γ-quanta of ^{60}Co. This high E_a characterizes the H_2 desorption through the barriers at the ends of the interstitial channels of the bundles in which the tube surfaces have radiation-induced defects.

The gases desorption rates obey the Arrhenius law at high temperatures, deviate from it with temperature reduction and become constant at low temperatures. These results indicate the quantum nature of gas outflow from carbon nanotube bundles. We have introduced a crossover temperature T_0 below which the quantum correction contributes significantly to the activation energy desorption. The temperature T_0 is a linear function of the inverse mass of the gas molecule, which is consistent with theory [3].

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