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Positron Annihilation In Carbon Nanotubes

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Abstract. Positron annihilation lifetime spectra have been measured in carbon nanotubes being pressed as a function of pressure up to 1536MPa. In addition, positron lifetime experiments for carbon nanotubes in vacuum, nitrogen and air have been performed respectively. Lifetimes have been obtained using LIFETIME program. The results display a single-component positron annihilation lifetime. Positron lifetime for carbon nanotubes decreases as the pressure increases, but lifetime is basically consistent after the pressure of 960MPa. Positron annihilation lifetime for carbon nanotubes in air is the shortest whereas the lifetime in vacuum the longest. We conclude that a positron annihilates with an electron on the external surface of carbon nanotubes.

Introduction

Since the discovery of carbon nanotubes by S. Iijima[1] in 1991, many experimental investigations have been performed on the materials with the techniques including scanning electron microscopy(SEM), transmission electron microscopy(TEM), atomic force microscopy(AFM), scanning tunneling microscopy(STM), Raman spectroscopy and X-Ray diffraction(XRD) etc. Positron annihilation spectroscopy is also the powerful technique employed to characterize the physical properties of carbon nanotubes. In previous work Ma Xing-Kun and his partners have measured positron lifetime spectra in two kinds of carbon nanotubes powders and obtained three lifetime components in one sample and four lifetime components in the other. [2] They assigned the short lifetime component to be the positron annihilation in the nanotubes. At the same time Yutaka Ito etc have also reported their experimental measurement on the positron lifetime of carbon nanotubes with only one component of 387ps. They described that positron annihilation takes place on the surface of the tubes. [3] In addition, one lifetime component was considered in the carbon allotrope C60/C70, which has the similar structure with carbon nanotubes. [4] In this work we performed the positron lifetime experiments for single-walled carbon nanotubes under the various pressures and those in different gas-adsorption, and then gave our conclusion that a positron annihilates with an electron on the external surface of carbon nanotubes.

Experiments

The carbon nanotubes were prepared as powder using CVD by Chengdu Organic Chemicals Co.Ltd. CAS. Before the measurements, the samples were pressed into 15 couples of disks with a diameter of 13 mm and a thickness of about 2 mm as a function of pressure up to 1536Mpa. Positron source used was ^{22}Na. Positron lifetime spectra measurements were carried out by a fast-fast coincidence system with a time resolution of 240ps (FWHM). The obtained lifetime spectrum was resolved using a least-squares method in the LIFETIME program. In the pressure experiments the samples were measured at ambient temperature. In the experiments of nitrogen-adsorption and air circumstance the gas pressure was kept in 1 atm and the temperature in 120 centigrade, but in the experiments with no gas-adsorption, the sample room was kept 120 centigrade in vacuum about 10^{-1} torr.

Results and discussion

By resolving the original spectra of positron lifetime measurements one lifetime component for all the samples was obtained. Figure1 illustrates that positron lifetime of single-walled CNT vs pressure. The positron lifetime values of the samples decrease in the rough with an exponential rule as the pressure increases gradually in the range of 6*48MPa~16*48MPa. After the pressure of 20*48MPa the positron lifetime of the nanotubes keeps constant value approximately. In the samples the positrons annihilate with the electrons either inside the nanotubes or on the external surface of the nanotubes. When the samples are pressed the exterior space of the nanotubes will reduce to the large extent. And then the electron density that is seen by the positron will increase. This maybe leads to a decrease of positron lifetime. And in the pressure range of 20*48MPa~32*48MPa, the exterior space of the nanotubes is not changed in the biggish range. So positron lifetime keeps constant basically.

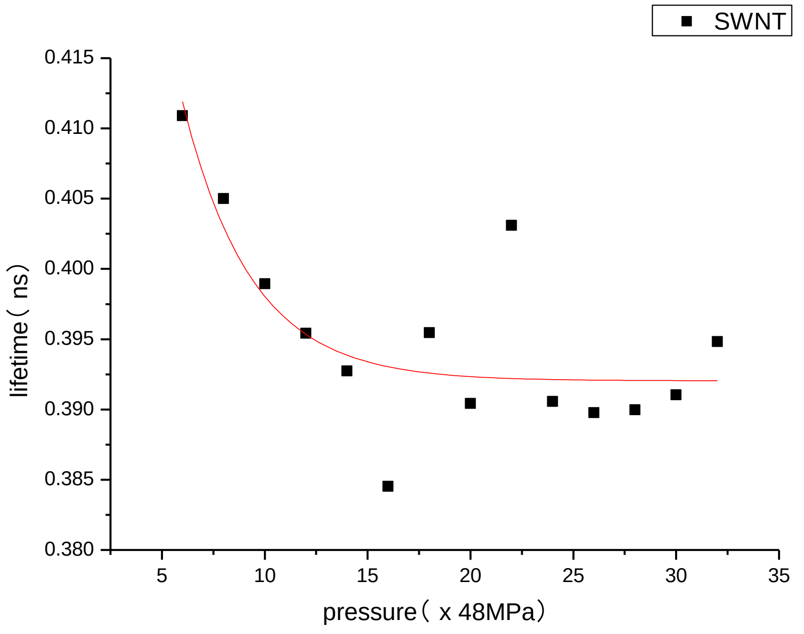

Figure 1: Positron lifetime of single-walled CNT vs pressure

Figure 2 shows positron lifetime of single-walled CNT in vacuum, nitrogen and air. The lifetime value of single-walled carbon nanotubes in vacuum is 398.4ps, which is the longest. At the same time the lifetime value of the same sample in air is 380.8ps, which is the shortest. The positron lifetime of single-walled carbon nanotubes in nitrogen is shorter than that in vacuum because the local electron density that is seen by the positron increases when nitrogen molecules adsorb on the external surface of the nanotubes. Additionally, in the air circumstance the positron lifetime decreases again because oxygen molecules exist in the air in the proportion of 4 to 5 and the oxygen molecule is the quenching gas for positron. [5] According to the analysis of the two measurements above we conclude that a positron annihilates with an electron on the external surface of single-walled carbon nanotubes.

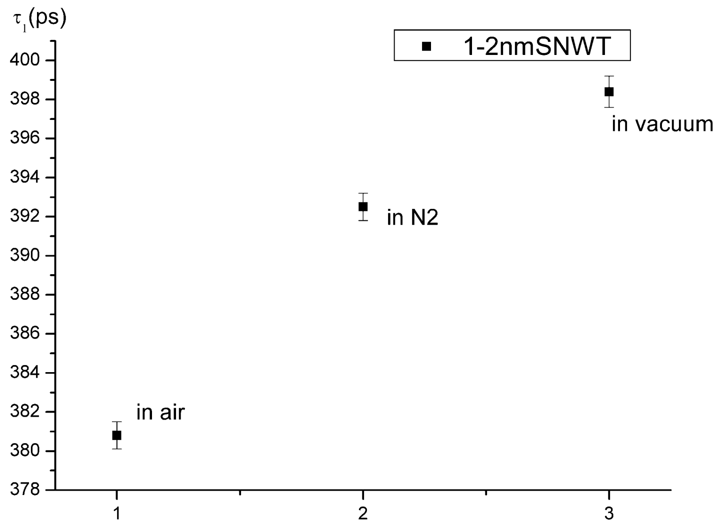

Figure 2: Positron lifetime of single-walled CNT in vacuum, nitrogen and air

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