INFRARED DETECTORS BASED ON SELF-ORGANIZED CARBON NANOTUBE ARRAYS

Final Report

JPL Task 939

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A. OBJECTIVES

The objective of this study is to explore the possibility of using carbon nanotubes for infrared detector applications. The unique structural and electronic properties of carbon nanotubes (CNTs) have generated great interest in using this new class of material for a wide range of device applications. Electrically, depending on the structure, CNTs can be either semiconducting or metallic, and can behave as quantum wires. Although the technology for fabricating CNTs in macroscopic quantities has been developed previously, the material produced tended to be entangled (spaghetti-like), and was difficult to process. Recently, our collaborators at Brown University (Prof. Jimmy Xu's group) have been able to produce **arrays of highly-ordered carbon nanotubes** fabricated on **nano-channel alumina (NCA)** plates. Unlike nanotubes fabricated by other means, which tended to be entangled bundles or random matrices of CNTs with varying dimensions, samples produced by the new technique are highly-ordered, large-area, two-dimensional arrays of densely-packed CNTs with unprecedented uniformity in diameter, length and orientation. These dense (10^{11} cm^{-2}) arrays contain nanotubes

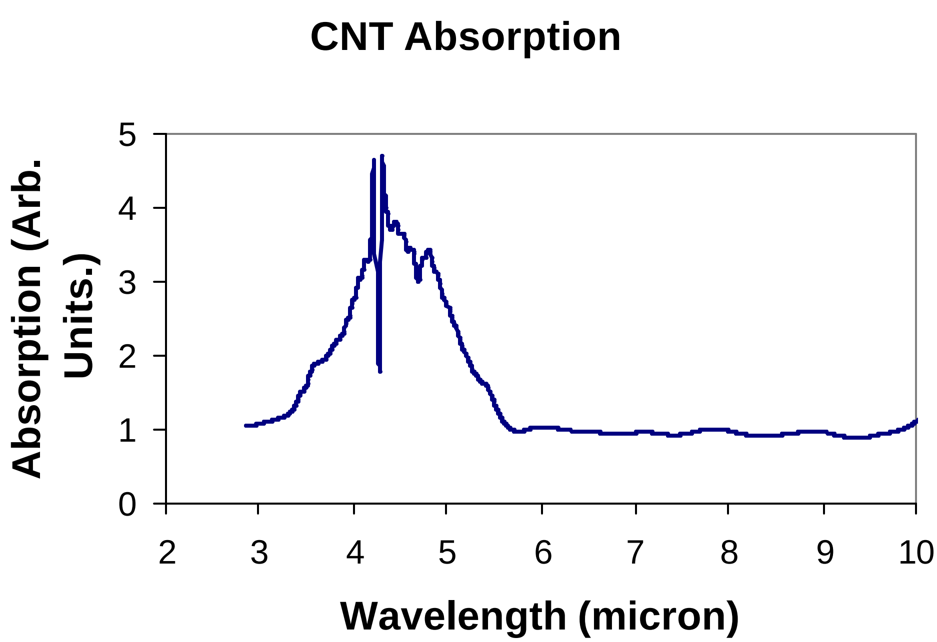

Figure 1. Infrared absorption characteristics of ordered carbon nanotubes grown on nano-channel alumina template.

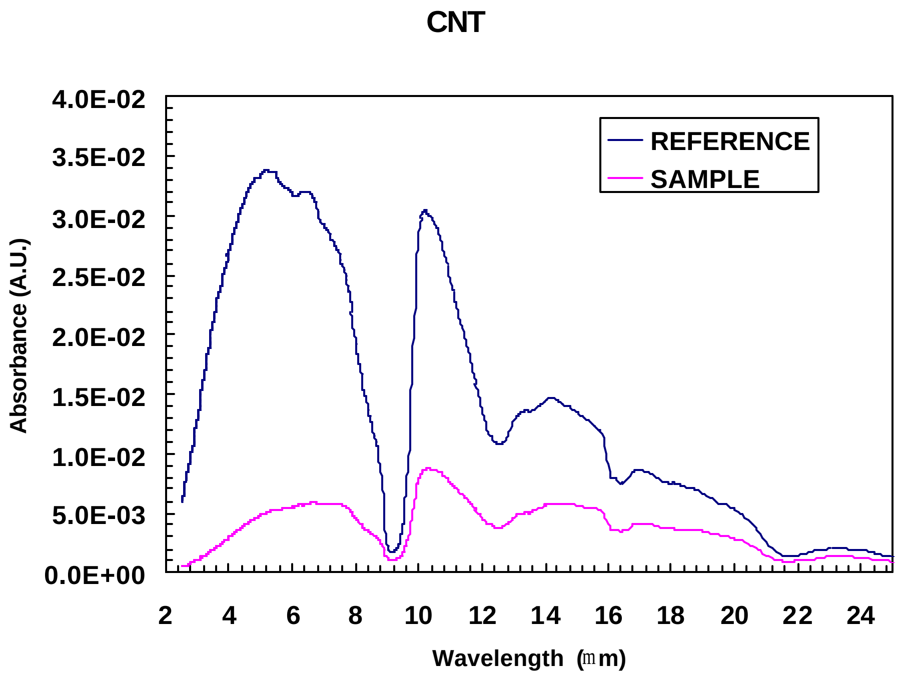

Figure 2. Infrared absorption characteristics of aligned carbon nanotubes grown at JPL on silicon substrate.

with selectable diameter sizes ranging from 10 to 350 nm, and lengths of up to 100 µm. The inter-tube spacing in the CNT arrays can be made to be as small as 30 nm. In contrast, the smallest achievable feature size using the much more expensive and time-consuming process of electron-beam lithography is 100 nm. This breakthrough material growth technology has made carbon nanotubes amenable to planar processing, and brought device applications to within reach. For this study in particular, we intend to test CNT arrays for infrared detector applications.

B. PROGRESS AND RESULTS

We have measured the infrared response of carbon nanotube samples obtained from Prof. Jimmy Xu's group at Brown University. These samples were grown on nano-channel alumina templates which, in turn, were grown on aluminum substrates which are opaque in infrared. The aluminum substrates must be removed before infrared response can be measured in the Fourier Transform Infrared spectrometer. This process requires considerable care in order that the carbon nanotubes themselves are not damaged during the process. The sample shows peak response in the 3 to 5 micron wavelength regime, but drops off at longer wavelengths (see Figure 1). We believe the drop-off in infrared response may be due to the reflection characteristics of the alumina template.

The unfavorable characteristics associated with the aluminum substrate processing and alumina template reflections led us to look for alternative solutions. We were able to obtain samples of dense, aligned carbon nanotubes grown on silicon substrate from Michael Hoenk, Michael Bronikowski, and Brian Hunt at JPL. Silicon substrates are infrared-transparent and greatly simplify sample preparation. Infrared response is shown in Fig. 2. The response seems to be over a broad spectrum and extends to 20 microns. Good absorption quantum efficiency, shown in Fig. 3, is observed over a wide spectral range.

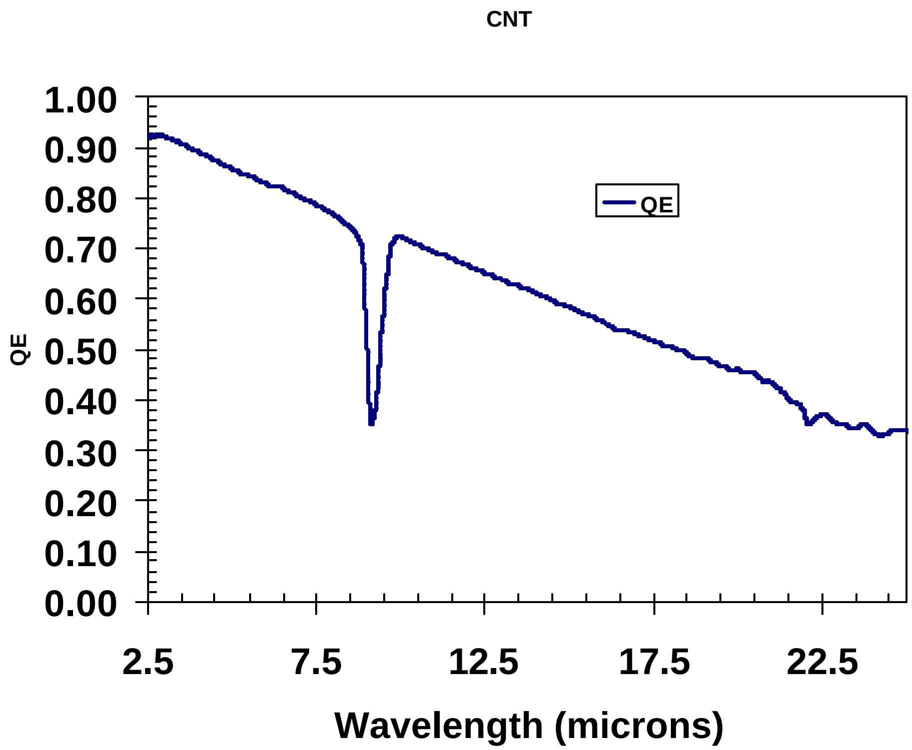

Figure 3. Absorption quantum efficiency of aligned carbon nanotubes grown on silicon substrate.

C. SIGNIFICANCE OF RESULTS

The results indicate that for infrared absorption applications, aligned carbon nanotubes grown on silicon substrates are probably better candidates than those grown on nano-channel alumina templates. Further advances in carbon nanotube growth techniques allowing the control of tube size would make them more favorable for infrared applications.

D. FINANCIAL STATUS

The total funding for this task was $25,000, all of which has been expended.

E. PERSONNEL

Prof. Jimmy Xu of Brown University supplied us with arrays of highly-ordered carbon nanotubes fabricated on nano-channel alumina (NCA) plates. Michael Hoenk, Michael Bronikowski, and Brian Hunt from JPL supplied the samples of aligned carbon nanotubes grown on silicon substrate.

F. PUBLICATIONS

None

G. REFERENCES

[1] J. Li, C. Papadopoulos, M. Moskovits and J. M. Xu, "Highly-ordered carbon nanotube arrays for electronics applications," *Appl. Phys. Lett.* 75, 367 (1999).