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XAFS study of transition-metal doped DNA

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1 Introduction

There has been no general consensus about the electrical conductivity of deoxyribonucleic acid (DNA). Kasumov et al. [1] directly measured the electrical resistivity of double-stranded DNA with rhenium/carbon (Re/C) bilayer electrodes, and found that DNA was metallic down to 50 mK and reported a proximity effect of the superconductivity of the metallic rhenium. On the other hand, Porath et al. [2] have directly measured the electrical conductivity of synthetic DNA [poly(G)-poly(C)] with a length of 10 nm to find a semiconducting behavior with the temperature-dependent energy gap of 2-4 eV. By doping DNA with transition-metal ions [3], metal cations are substituted for the hydrogen bonds in between the bases, making one-dimensional chains. In this study, we observed the valence states of such transition-metal ions by measuring XAFS (X-ray absorption fine structure) spectra. The advantage of this technique is that there is no need for electrical contact or current flow, which has been identified as possible errors leading to the controversial interpretations of the electronic states in DNAs.

2 Experiment

The fabrication of transition-metal doped DNAs are described in Ref. [3]. We performed XAFS measurements of Mn and Fe doped DNAs at Photon Factory BL-12C by using the fluorescence mode at room temperature.

3 Results and Discussion

Figure 1 shows the Mn *K* edge XAFS of the Mn doped DNA with reference data of Mn, Mn^{2+} (MnO), and Mn^{4+} (MnO_2). The spectrum of DNA is similar to that of MnO, meaning that the doped Mn is 2+. Figure 2 shows the Fe *K* edge XAFS of the Fe doped DNA with reference data of Fe and Fe^{3+} ($FeCl_3$). The spectrum of DNA is similar to that of $FeCl_3$, meaning that the doped Fe is 3+. This result is also consistent with the red color of Fe doped DNA. Pure Mn^{2+} and Fe^{3+} ions show insulating behaviors, so controlling the valence of such ions will be the key for realizing one-dimensional electronic transport in DNA. Doping other ions (Ti, V, Cr, Co, Ni, and Zn) will be interesting. We are now analyzing EXAFS data to obtain the local environment of Mn and Fe ions. We are also planning to measure aqueous solutions of transition-metal doped DNA.

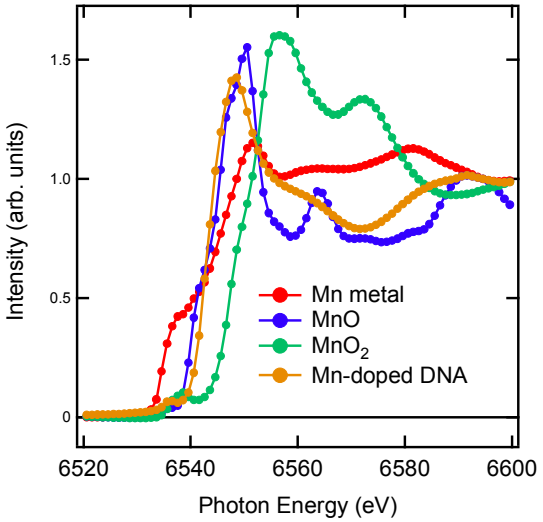

Fig. 1: Mn *K* edge XAFS of the Mn doped DNA with reference data.

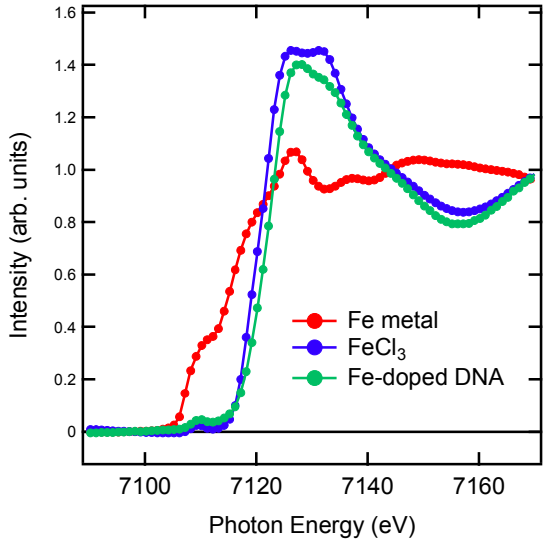

Fig. 2: Fe *K* edge XAFS of the Fe doped DNA with reference data.

References

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