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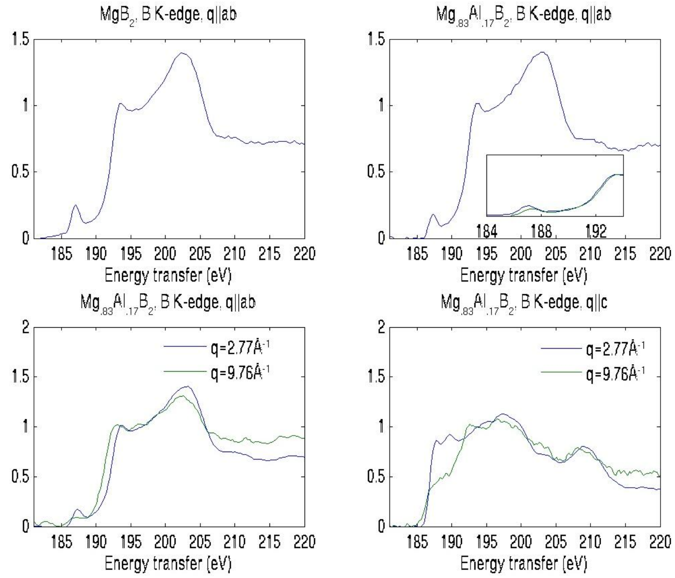
Report:

We have conducted an inelastic x-ray scattering investigation of a series of aluminum substituted MgB_2 single crystal superconductors ($Mg_{1-x}Al_xB_2$). The aim of the experiment was to study the effect of aluminum substitution on the electronic structure and excitation spectrum and to answer questions related to the superconducting properties of MgB_2 and aluminum doped ($Mg_{1-x}Al_xB_2$) compounds. We measured the boron K-edge x-ray Raman spectra from single crystal samples to probe the filling of the empty electronic states of boron induced by the aluminum substitution. The experiment was made possible by the recent growing of single phase $Mg_{1-x}Al_xB_2$ single crystals with high aluminum content[1]. Our previous experiments on single crystal MgB_2 at ESRF have highlighted the capabilities of our experimental method for probing the electronic structure and the excitation spectrum of MgB_2[2].

The discovery of relatively high critical temperature $T_c \approx 39$ K of superconductivity in MgB_2[3] has sparked off a considerable interest on the properties of this and other binary metal compounds[4]. MgB_2 is now understood to be a phonon mediated Eliashberg superconductor with two superconducting energy gaps originating from the boron $p\sigma$ and π bands due to different electron-phonon coupling strengths. This picture is consistent with the destruction of superconductivity with the filling of the boron p band holes by electron doping induced by aluminum substitution for magnesium[5].

X-ray Raman scattering probes the empty electronic states providing information similar to x-ray absorption spectroscopy. However, the x-ray Raman cross section is sensitive also to the magnitude of the momentum transfer in the inelastic scattering process. By tuning the momentum transfer final states different from those selected by the dipole rule can be reached. Further advantage over x-ray absorption spectroscopy is that as an inelastic scattering probe, x-ray Raman investigation can be done using hard x-rays. Due to this fact x-ray Raman scattering is not surface sensitive unlike x-ray absorption done using soft x-rays. This is an advantage with hygroscopic MgB_2 single crystals that generally require careful sample preparation when studied using surface sensitive techniques.

We used three $Mg_{1-x}Al_xB_2$ single crystals with x = 0.17, 0.07 and 0 with dimension of roughly 0.5 × 0.5 × 0.1 mm[3]. The x-ray Raman spectra were measured using the ID16 eV-resolution backscattering spectrometer using Si(111) spherical analyzer crystal. We measured along two crystallographic directions (with *q* parallel and perpendicular to the *ab*-planes) the x-ray Raman spectra at the boron K-edge from x = 0.17 and 0 samples and also the spectrum from x = 0.07 sample with *q* parallel to *ab*-planes. We used $q = 2.77Å^{-1}$ with the scattered photon energy fixed at 7.907 keV and analyzed the scattering spectrum using a (444) reflection. In addition, we measured a high *q* spectrum from x=0.17 sample with *q* parallel and perpendicular to the *ab*-planes. For these spectra the scattered photon energy was fixed at 9.885 keV with $q = 9.76Å^{-1}$ and we used the (555) reflection from the analyzer crystal. Energy resolution was 1.0 eV for the specta measured using the (444) reflection and 1.5 eV for the high *q* spectra measured using the (555) reflection. Typical signal above the B K-edge was around 150 cps and the statistical accuracy in the accumulated spectra roughly 0.3%.



Picture 1 B K-edge spectra from Al substituted MgB_2.

Figure 1. shows examples of the measured B K-edge spectra after inelastic background removal. The upper left panel shows the *q* || *ab* spectrum from pure MgB_2 while the upper right panel shows the spectrum from aluminum substituted sample with x = 0.17 substitution level. The inset compares the pre-edge region spectra of these two samples, revealing a decrease in the intensity of the pre-peak in the aluminum substituted (green line) sample. Lower panels show the momentum transfer dependance of the B K-edge for the Al substituted sample with x = 0.17. Further analysis of the experimental results is under way and a manuscript of the results is under preparation.

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