Momentum transfer resolved EELS study of anisotropic carrier plasmon in $Cs_{0.33}WO_3$

Sato, Y.[1], Terauchi, M.[2] and Adachi, K.[3]

[1] IMRAM, Tohoku University, Japan, [2] IMRAM. Tohoku University, Japan, [3] Sumitomo Metal Mining Co., Ltd., Japan

Hexagonal cesium doped tungsten oxide, $Cs_{0.33}WO_3$ (CWO), is applied for a heat-shielding filter. The mechanism of heat-shielding, i.e. electromagnetic wave scattering in near infrared (NIR) energy region, is attributed to plasmon excitation due to carrier electrons [1]. The behavior of the carrier electron in CWO is a key factor for the performance of the filter, which has a high EM scattering probability in wide range of NIR region and a high transmittance in the visible light energy region. Since CWO is hexagonal symmetry, the carrier electron should have anisotropic property. It is important to clarify how the anisotropic behavior of the carrier electron is affected to the NIR scattering. In order to probe anisotropic properties, it is effective to conduct the momentum transfer (q) resolved EELS measurement. The q-dependence of EELS spectra provide important information of the dielectric properties depending on q transfer, which are intrinsic to the electronic structure of the CWO. We have adjusted lens conditions of a monochromator TEM to conduct qEELS measurement in NIR region. Using this instrument, the q-dependence of the carrier plasmon of the CWO are investigated to reveal the origin of the NIR scattering and the electronic structure of CWO.

qEELS measurement is conducted by a monochromator TEM, which consists of a schottky type FEG with a monochromator, an omega-filter as analyzer, and lens column of JEM-2010FEF. A rectangular slit as a q-selected slit is inserted at a plane of the electron diffraction pattern just above the omega-filter. qEELS spectra are obtained as E-q map as shown in figure 1. The energy and momentum transfer resolutions in qEELS measurement mode are 0.22 eV and 0.04 $Å^{-1}$, respectively, at 100kV operation.

Figure 1 shows E-q Maps obtained of CWO, where the **q** directions are (a) **q**//$11\bar{2}0$ (along *ab*-plane) and (b) **q**//0002 (along *c*-axis). Figure 2 shows the spectral intensity profiles in rectangles of Fig.1 (a) and (b). In q=0, a plasmon peak and a shoulder structure are observed in the NIR region (assigned as A and B). In directing **q** along *ab*-plane, the plasmon peak-A is dominantly excited. On the other hand, the plasmon peak-B is dominant when **q** is along c-axis. These results indicate that two plasmon modes along *ab*-plane and *c*-axis exist in CWO. Components of conduction bands occupied by carrier electrons in CWO are tungsten 5d orbitals, which compose 3D metallic bands and a 1D metallic band along *c*-axis [3]. The anisotropy of the two plasmon dispersions reflect the two kinds of metallic bands depending on the crystal directions. Therefore, the wide-range NIR scattering performance of the heat-shielding filter is attributed to the two anisotropic plasmon modes in NIR region.

References

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Fig. 1

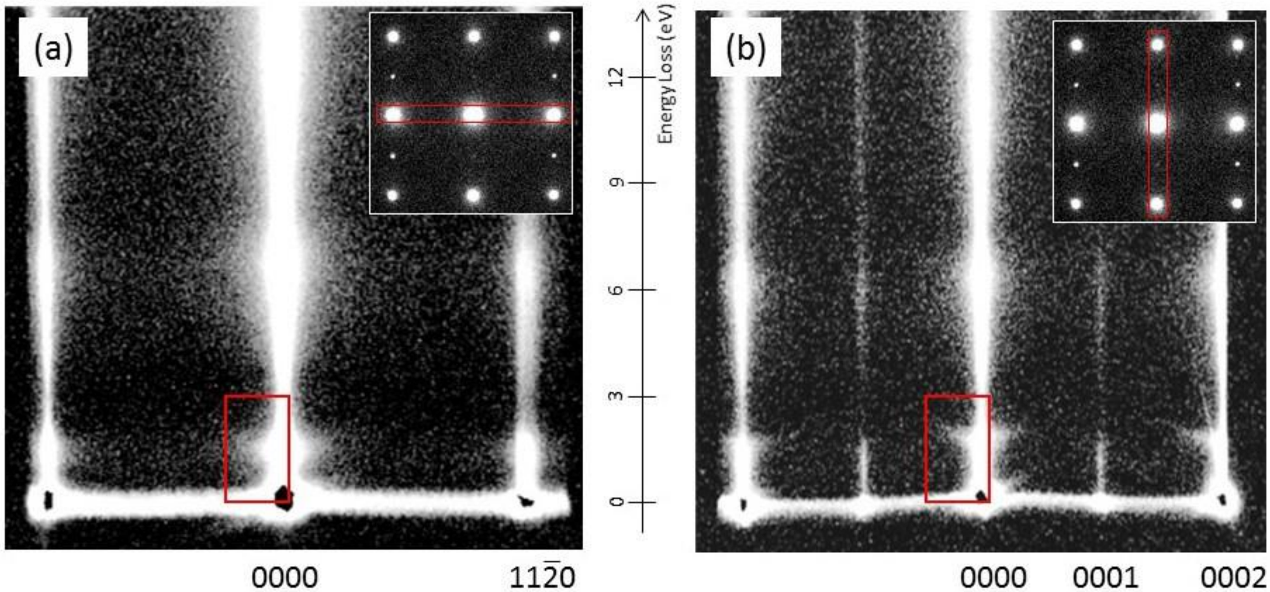

Figure 1, E-q maps of $Cs_{0.33}WO_3$. (a) q direction is along $11\bar{2}0$ (*ab*-plane) and (b) is along 0002 (*c*-axis). Inserted figures are electron diffraction pattern of CWO taken with the [$1\bar{1}00$].

Fig. 2

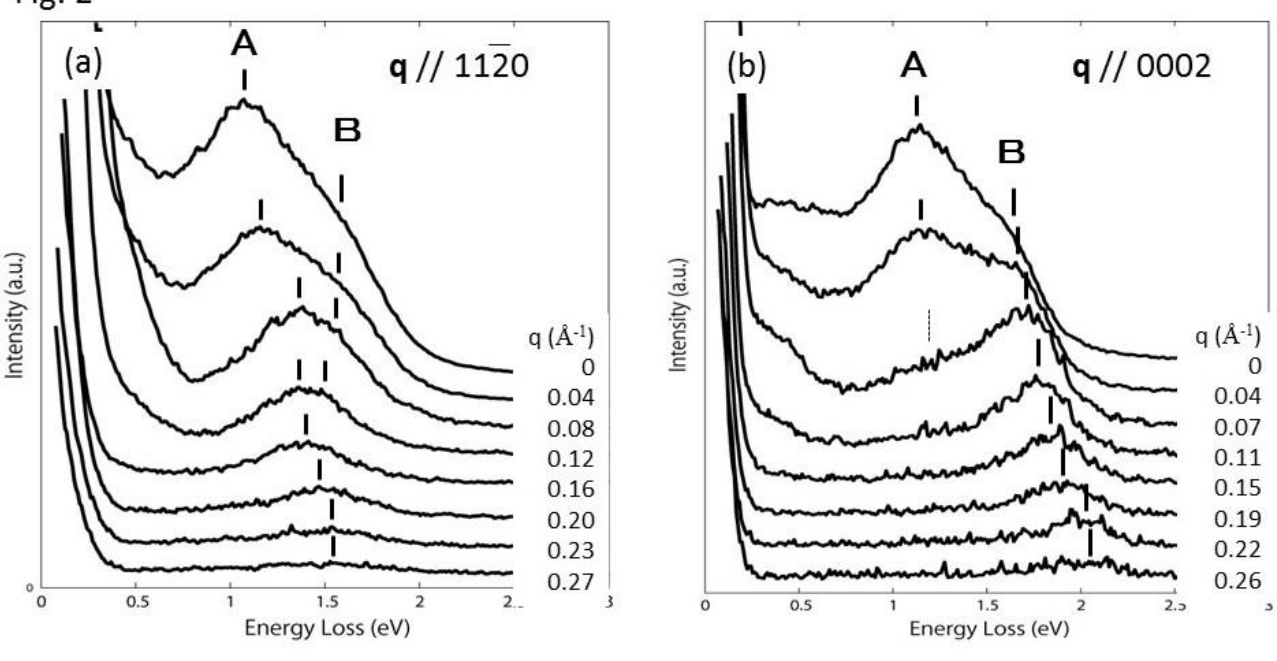

Figure 2, Line profiles of q-EELS spectra with q transfer along (a) $11\bar{2}0$ (*ab*-plane) and (b) 0002 (*c*-axis).