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Auger-Auger Coincidence Spectroscopy of Mn in MnO

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Beamline(s): U16B

Introduction: Atoms that are highly excited due to the presence of a hole in an inner shell often relax via an Auger transition in which the inner-shell hole is filled by a less tightly bound electron and the excess energy is carried off by yet another electron which exits the atom. This auto-ionizing process results in a final state with two holes. If one or more of these holes is in an inner shell, then the initial Auger transition can be followed by one or more additional Auger transitions. These so-called “Auger cascade” processes have been studied extensively in molecular and atomic gases [ref1]. Here we present results of the first direct measurements of the energy spectra due to electrons emitted in the second and third Auger decays in this cascade. This measurement was made possible by the introduction of a new type of electron coincidence spectroscopy from solids: Auger-Auger Coincidence Spectroscopy (AACS). These, our first AACS measurements, are of Mn core-valence-valence (CVV) transitions measured in time coincidence with the Mn core-core-valence (CCV) and Mn core-core-core (CCC) Auger transitions in MnO.

Methods and Materials: Using AACS (see above), we have measured the Mn $M_{2,3}VV$ Auger spectrum from a single-crystal sample of MnO in time coincidence with Auger electrons emitted from prior Mn CVV Auger transitions (either Mn $L_{2,3}M_{2,3}V$ or Mn $L_{2,3}M_{2,3}M_{2,3}$). These measurements were performed using our Auger-Photoelectron Coincidence (APECS) apparatus at beamline U16B, which is described in detail elsewhere [ref2]. We have also measured the corresponding so-called reverse coincidence spectra, i.e. the Mn $L_{2,3}M_{2,3}V$ and Mn $L_{2,3}M_{2,3}M_{2,3}$ Auger spectra in coincidence with Mn $M_{2,3}VV$ Auger electrons. The MnO surface was cleaned *in-situ* by repeated Ar-ion sputtering and subsequent annealing to 630°C in ultra-high vacuum (few $\times 10^{-10}$ Torr). Two electron energy analyzers were used to perform the AACS measurements. For the “forward scans”, one analyzer remained fixed on the CCV or CCC Auger emission line of interest (i.e. Mn $L_{2,3}M_{2,3}V$ or Mn $L_{2,3}M_{2,3}M_{2,3}$), while the other was scanned through the energy range of the Mn $M_{2,3}VV$ emission. For the “reverse” scans, one analyzer remained fixed in the center of the Mn $M_{2,3}VV$ Auger emission spectrum while the other was scanned through the energy ranges of Mn $L_{2,3}M_{2,3}V$ or Mn $L_{2,3}M_{2,3}M_{2,3}$ Auger spectra.

Results: In the figure below, we present two Mn $M_{2,3}VV$ AACS spectra, measured in coincidence with either the Mn $L_{2,3}M_{2,3}V$ (solid line) or Mn $L_{2,3}M_{2,3}M_{2,3}$ (dashed line) Auger lines. In this figure, we also present, for comparison, the non-coincident (so-called “singles”) Mn $M_{2,3}VV$ Auger spectrum (solid line), scaled to match the AACS spectra at 20eV (outside the MVV range). Note that the Mn $M_{2,3}VV$ spectrum is nearly unobservable in the singles spectrum. Notice also the significant difference between the two AACS spectra: the Mn $M_{2,3}VV$ AACS spectrum measured in coincidence with the Mn $L_{2,3}M_{2,3}M_{2,3}$ Auger line exhibits a relatively sharp peak at 26eV electron kinetic energy which is absent in the Mn $M_{2,3}VV$ AACS spectrum measured in coincidence with the Mn $L_{2,3}M_{2,3}V$ Auger line. We posit that this extra feature is a result of the fact that the intermediate state left after the $L_{2,3}M_{2,3}M_{2,3}$ transition has two $M_{2,3}$ holes and can decay by two subsequent Auger transitions. In the first of these Auger decays, one of the $M_{2,3}$ holes is a spectator and two holes are left in the valence band. In the second transition, the spectator $M_{2,3}$ is filled and four holes are left in the valence band (the energy required to create the 4^{th} valence hole could account for the low energy shift of the extra feature). A quantitative analysis of these data is currently underway.

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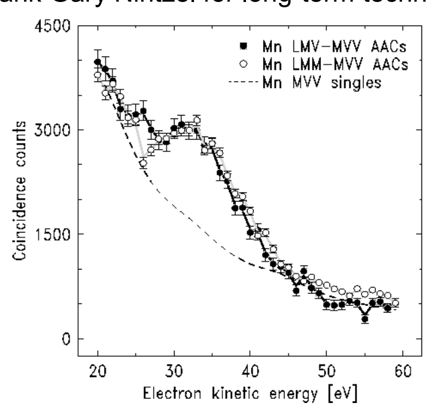
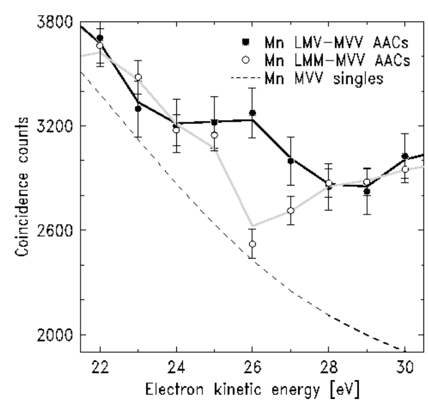
References:

[ref1] See Phys. Rev. A **53**, R3716 (1996) and references therein.
[ref2] Rev. Sci. Instrum. **63,** 3013 (1992).



AACS spectra from MnO



Closeup of 26eV feature