# Resonant Photoemission at the $L_{III}$ thresholds of Ni and Co metal

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The appearance of electron-correlation satellites in the high-energy excitation spectra of $3d$ transition elements, rare earths, and actinides has attracted considerable scientific interest in the past two decades. Among these, the 6-eV valence-band PE satellite of Ni metal and the possible existence of similar structures in the valence-band PE spectra of Co have been widely discussed in the literature [1-3]. Experimentally, the Ni satellite has been identified as a two-hole bound state by means of resonant photoemission (PE). Here, close to the $2p$ and $3p$ x-ray absorption thresholds, the interference of the direct PE channel with the Auger-decay channels of the $2p \rightarrow 3d$ or $3p \rightarrow 3d$ core-excited states leads to strong variations in the PE cross section and, in particular, to a resonant enhancement of the PE cross section for that particular final state, which is also populated by an Auger decay of the dipole-excited $3d$ state. However, it is important to decide whether the observed enhancement of the PE signal reflects really an interference phenomenon or simply consists on an incoherent superposition of PE and Auger processes [4].

In the present contribution, we report on a resonant PE study of polycrystalline Ni and Co metal at the $2p$ soft-x-ray absorption threshold [5]. We show, that the huge resonance observed is mainly due to a Coster-Kronig signal.

The measurements were performed with the SX700/II high-performance soft-x-ray monochromator operated by the Freie Universität Berlin at the Berliner Elektronenspeicherring für Synchrotronstrahlung (BESSY). The samples were studied in form of polycrystalline materials and cleaned in situ by scraping with a diamond file.

The insets in Figs. 1 and 2 show the XANES spectrum of Ni and Co metal, respectively, taken at the $L_{III}$ absorption thresholds. The main part of Figs. 1 and 2 display valence-band PE spectra of Ni and Co metal, respectively, taken at different photon energies around the absorption maximum and normalized to the beam current. In both cases, on resonance, at $h\nu = 854.5$ eV for Ni and $h\nu = 778.7$ eV for Co, a huge enhancement of the electron emission is observed. For photon energies above the absorption maximum, a strong Coster-Kronig Auger peak moves away from the $3d$ PE signal. In order to get a quantitative description of the phenomenon, the spectra were numerically analyzed by superposition of a PE signal with an Auger line profile. The respective line shapes were deduced from spectra taken far away from resonance. As a result of this analysis, the spectra are described by the superposition of a weak PE signal and a strong, resonantly enhanced Coster-Kronig Auger spectrum, which is not coupled to the PE channel.

The large intensity of the Auger signal relative to the $3d$ PE signal is simply related to the fact that the core-excitation cross section for a $2p$ core state is more than 1.5 orders of magnitude larger than the PE cross section for a $3d$ band electron. The resonant increase in the intensity of the $L_3M_{4,5}M_{4,5}$ Auger signal on resonance reflects simply the high density of unoccupied $3d$ states close to the Fermi level.

In conclusion, we showed that the resonant enhancement of the PE spectra of Ni and Co metal in the $2p \longrightarrow 3d$ resonance, is almost completely due to an incoherent superposition of the valence-band PE signal and the corresponding Auger emission. This clear difference to the resonant PE behavior in rare-earth systems is probably caused by

a weaker localization of the $3d$ states, where a strong hybridization of the dipole-excited state with the surrounding $3d$ bands leads to a delocalization and thereby to a loss of coherence [5].

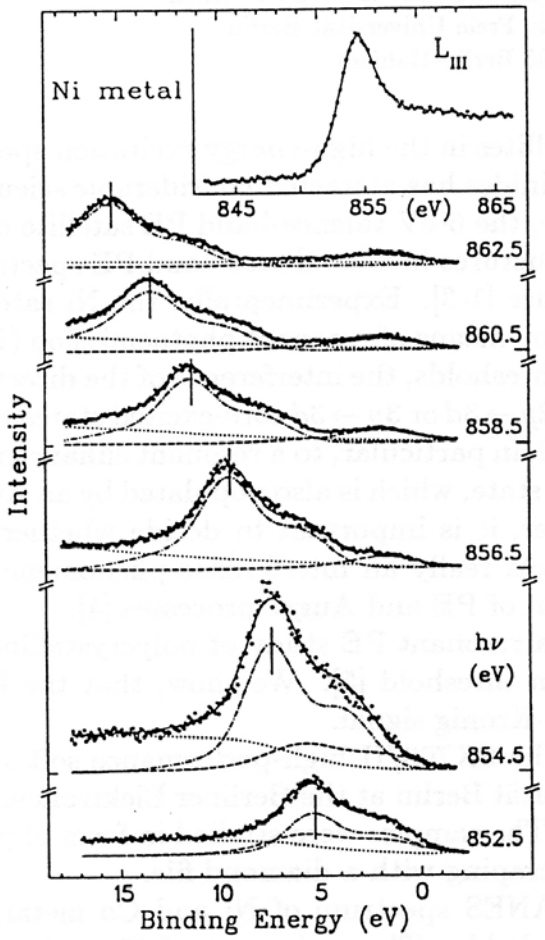


Fig. 1: Photoelectron spectra of Ni metal taken at various photon energies close to the $L_{III}$ threshold.

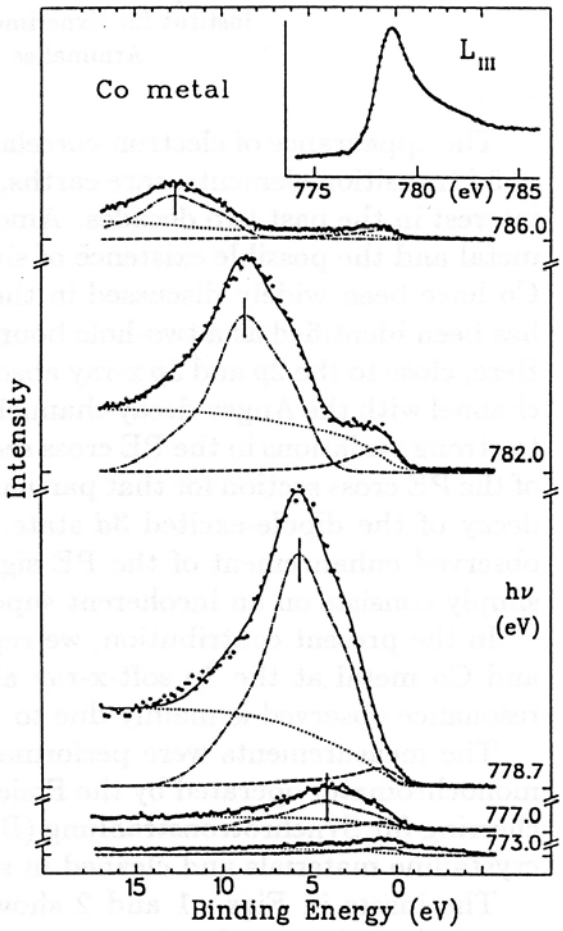


Fig. 2: Photoelectron spectra of Co metal taken at various photon energies close to the $L_{III}$ threshold.

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