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Electronic structure of metallic nickel colloids

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Introduction

Small metal clusters with nano-scopic dimensions have excellent prospects for a wide range of technological applications. The reasons for the versatility lie in the characteristic physical properties that originate from finite-size or quantum-confinement effects.

Recently, we have prepared metallic nickel colloids with nano-porosity by the thermal decomposition of nickel/poly-vinyl alcohol composite films [1]. The TEM photograph showed that the average particle size of nickel colloids was about 10 nm. Adsorption isotherms of nickel colloids indicated that the colloids had both mesopores and micropores. Because of their unique structural properties, their electronic structures of the surface atoms will be significantly different from those of the bulk.

In this work, we report the contribution from the surface atoms of nickel colloids to the inelastic scattering of photoelectrons by means of the XAFS analysis.

Experimental

The nickel colloids were prepared by the thermal decomposition of nickel/poly-vinyl alcohol composite films. The detail preparation methods are described elsewhere [1]. The resulting compounds were characterized by using of XPS, FE-SEM, and TEM. The XAFS measurements were performed on Ni *K*-edge for the Ni foil and for the nickel colloids at KEK PF, BL-7C beam line.

Results and discussion

The XANES peaks of nickel colloids shifted to higher energies and became a broadening (Figure 1). The former is due to the shorting of the lattice parameter, the latter a consequence of the colloid-size distribution [2]. Table 1 shows the coordination number (*N*), nearest-neighbor interatomic distance (*R*), Deby-Waller factor (σ^2), and the electron mean free path (λ) of nickel foil and nickel colloids calculated from Fourier spectra and from *k*-space analysis. The results of EXAFS analysis showed the change in the parameters of the nickel colloids, comparing with those of Ni foil. An important parameter that will reflect the electronic properties of the surface is the electron mean free path. In small particles, the inelastic scattering of the photoelectrons is enhanced with respect to the bulk, because of the surface plasmon excitation [3]. Therefore, the electron mean free path of nickel colloids are smaller than those of the bulk. These results suggest that the surface electronic structures on the nickel colloids are strongly perturbed and are dominated by surface effects for the small colloids.

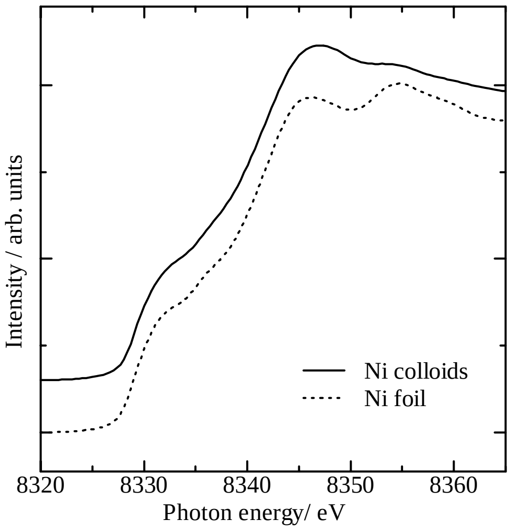

Figure 1: The XANES spectra of Ni foil (dotted line) and nickel colloids (solid line).

Table 1: The coordination number (*N*), nearest-neighbor interatomic distance (*R*), Debye-Waller factor (σ^2), and the electron mean free path (λ) of Ni foil and Ni colloids.

	N	*R* / nm	σ^2 / nm^2	λ / nm
Ni foil	12.0	0.249	5.48×10^{-5}	0.629
Ni colloid	9.5	0.246	6.08×10^{-5}	0.491

References

[1] Y. Hattori et al., Adv. Mater. 15, 529 (2003).
[2] A. Balerna et al., Phys. Rev., B31, 5058 (1985).
[3] J. Zhao and P.A. Montano, Phys. Rev., B40, 3401 (1989).

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