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c(2×2) CuMn /Cu(001) 表面二次元合金の表面磁性研究：Mn 2p 内殻吸収磁気円二色性

Surface magnetic property of c(2×2)CuMn/Cu(001) 2-dimensional ordered surface alloy: Probed by soft x-ray magnetic circular dichroism

木村昭夫 [1]，朝直俊介 [1]，神戸喬史 [1]，謝天 [1]，喬　山 [2]，室隆佳之 [3]，今田真 [4]，菅滋正 [4]，谷口雅樹 [1]

Kimura[1], S. Asanao[1], T. Kambe[1], T. Xie[1], S. Qiao[2], T. Muro[3], S. Imada[3], S. Suga[4], M. Taniguchi[1]

[1] 広島大学大学院理学研究科，[2] 広島大学放射光科学研究センター，[3]JASRI, [4] 大阪大学大学院基礎工学研究科

[1]Graduate School of Science, Hiroshima University [2]Hiroshima Synchrotron Radiation Center, Hiroshima University, [3]JASRI [4]Graduate School of Engineering Science, Osaka University

c(2×2) CuMn/Cu(001)表面二次元合金について Mn 2p 内殻吸収領域の磁気円二色性スペクトルを観測し，その温度依存性について調べた。その結果，L_3 吸収領域における XMCD スペクトルの積分強度が温度降下にしたがって，減少していく様子が明確に観測された。その積分強度が磁化に比例するものと考えると，その温度依存性はキュリー・ワイス則に従っていることが分かった。また，その温度依存性から，キュリー・ワイス温度（Θ）は21Kと見積もられた。この結果，は約20K以下で CuMn 表面二次元合金が強磁性に転移することが示唆された。

We have observed the temperature dependence of soft X-ray magnetic circular dichroism (XMCD) spectra in the Mn 2p core excitation region of c(2×2) CuMn/Cu(001) 2D ordered surface alloy. The temperature dependence of the XMCD integrated intensity obeys a Curie-Weiss law in the temperature range of 40-130K. The inverse plot of the XMCD integrated intensity as a function of temperature derives the Curie-Weiss temperature Θ=21K, suggesting the ferromagnetic transition below about 20K. This result is in strong contrast to the formerly reported result.

Crystalline Mn is known as an antiferromagnetic or a paramagnetic metal with a quite small magnetic moment. However, once Mn atoms crystallize with non-magnetic elements, like Sb and even an oxygen atom, ferromagnetism appears as is found in MnSb or in $La_{1-x}Sr_xMnO_3$ [1]. Very small amount of Mn in a semiconductor can also derive a ferromagnetism, as discovered in (Ga, Mn)As [2]. One possibly extend his idea to a low dimensional case. An example is a Mn based alloy fabricated on noble metal surfaces. Wuttig et al. discovered that Mn based two-dimensional (2D) ordered alloy can be formed on Cu(001) clean surface at a coverage of 0.5ML, where Mn and substrate atoms are alternatively placed forming a c(2×2) "checkerboard" structure as shown in Fig.1 [3]. A low energy electron diffraction (LEED) *I-V* measurement shows that c(2×2) CuMn surface alloy has a pronounced corrugation, in which Mn atoms in the first layer are displaced outwards by δz=0.30±0.02 Å, which is 17% with respect to the atomic distance in the bulk [3]. A theoretical band structure calculation predicts that the most stable magnetic state for c(2×2) CuMn ordered surface alloy is a /ferromagnetic structure in the ground state [4]. The theory also explains that the observed large corrugation of the Mn atoms are derived from the magnetism [4]. However, the experimental evidence of the ferromagnetic state of this surface alloy has not been obtained so far. The lack of the experimental evidence possibly comes from the lower ferromagnetic transition temperature (Curie temperature) as usually found in ultra-thin films with a couple of 3d transition metal monolayers. With this reason, we have tried to observe the soft X-ray magnetic circular dichroism (XMCD) spectra in the Mn 2*p* core absorption region at BL-25SU of SPring-8 [5]. The external magnetic field of -1.4T at the sample position was applied. The XMCD spectra were taken for a fixed direction of the magnetic field by 1Hz helicity switching of the incident circularly polarized undulator radiation. In the present report, the XMCD spectrum is defined as $\mu_- - \mu_+$, where μ_+ and μ_- represent the absorption coefficients for the direction of the magnetization parallel and anti-parallel to the photon helicity, respectively. Manganese was evaporated from an electron beam evaporation source with a water cooling shroud at a rate of 0.2ML/min. We finally observed very clear c(2×2) LEED pattern for 0.5ML Mn/Cu(001) as shown in Fig.2 (b). In Fig.3, the temperature dependence of the L_3 XMCD spectra are shown in the temperature range of 43K-136K. As shown in Fig.3 (a), we clearly find that the XMCD

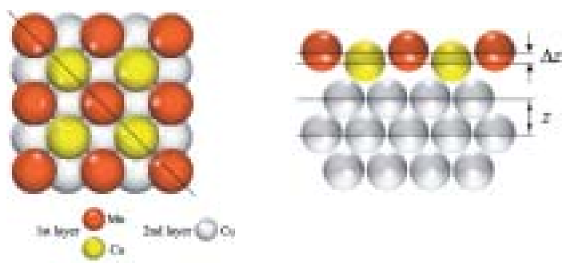

Fig.1: Surface structure of c(2×2) CuMn ordered surface alloy.

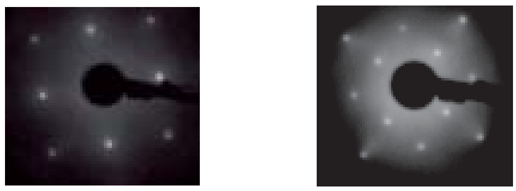

Fig.2: LEED patterns of (a) clean Cu(001) and (b) 0.5ML Mn/Cu(001)

(a)

(b)

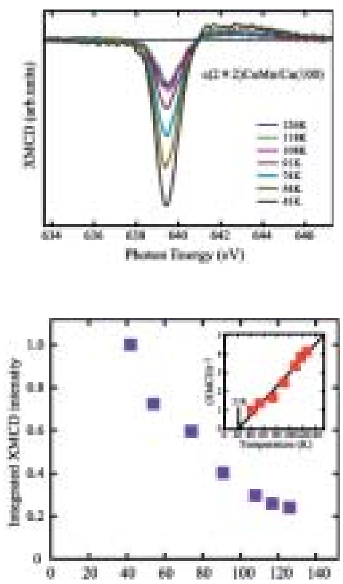

Fig.3: (a) Temperature dependence of the Mn L_3 XMCD spectra (see text). (b) The integrated intensity v.s. temperature. The inset shows the inverse plot of the XMCD integrated intensity v.s. temperature.

integrated intensity decreases with increasing temperature. The inset shows the inverse plot of the XMCD integrated intensity v.s. temperature. It can be recognized from this plot that the $(XMCD)^{-1}$ decreases linearly with decreasing temperature, which indicates that the magnetic susceptibility obeys a Curie-Weiss law above 40K for CuMn surface alloy. Besides, the estimated value of Curie-Weiss temperature Θ=21K suggesting the ferromagnetic phase transition below about 20K. This result is in strong contrast with the formerly reported experiment [6].

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