GdNi is a ferrimagnetic material with a Curie temperature $T_C = 69$ K which exhibits a large magnetocaloric effect, making it useful for magnetic refrigerator applications. We investigate the electronic structure of GdNi by carrying out x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) at $T = 25$ K in the ferrimagnetic phase. We analyze the Gd M$_{4,5}$-edge (3d - 4f) and Ni L$_{2,3}$-edge (2p - 3d) spectra using atomic multiplet and cluster model calculations, respectively. The atomic multiplet calculation for Gd M$_{4,5}$-edge XAS indicates that Gd is trivalent in GdNi, consistent with localized 4f states, except for Ce, Eu, Sm and Yb which can show mixed valency. The rare-earth 4f electrons in intermetallic alloys are usually considered to be localized, while the transition metal d electrons are considered to be delocalized or itinerant. It is well established that in intermetallics, most rare-earth atoms normally exhibit trivalent ground states, except for Ce, Eu, Sm and Yb which can show mixed valency. An important question that arises in such intermetallic alloys consisting of rare-earth and transition metal elements is the behavior of element specific magnetism.

While the rare-earth element is expected to show a local magnetic moment, the behavior of the transition metal magnetic moment is not so clear. It is well-known for many such alloys that when the concentration of the rare-earth ion increases, the magnetic moments of transition metal ions get reduced. It is expected that the transition metal 3d band will gradually get filled on increasing rare-earth ion content. This picture is called the charge-transfer model, and it successfully explain the properties of many, but not all R$_x$M$_y$ alloys (where R = rare-earth and M = Fe, Co, Ni, Cu).

There are some known exceptions to this model such as the alloy system Gd$_x$Fe$_{1-x}$ with $0.1 \leq x \leq 0.4$. Also, for GdNi$_2$ with a ferrimagnetic $T_C = 85$ K, while it was initially concluded that Ni is non-magnetic in samples prepared at ambient pressure, it was also shown that samples prepared under high pressures of 5 - 8 GPa showed a reduced $T_C \sim 60$ K which was attributed to holes in the Ni 3d band indicative of magnetic Ni ions. These results suggest that the Ni 3d-band is near a filling instability which can be controlled by sample preparation conditions such as high pressure, which results in creating holes in the Ni 3d band leading to Ni magnetic moments. Subsequently, an XMCD study showed a small but finite spin magnetic moment ($m_s = 0.14 \mu_B$) for Ni ions in GdNi$_2$. In this work, we investigate the electronic structure of GdNi, which has also been debated with respect to the charge-transfer model as discussed in the following.

GdNi is a binary alloy which undergoes a magnetic transition around $T_C = 69$ K, and exhibits a large magnetocaloric effect near $T_C = 69$ K. The magnetocaloric effect is the thermal response of a material when an external
magnetic field is applied or removed under adiabatic conditions. The crystal structure of GdNi is orthorhombic (CrB type structure, Space group CmCm No. 63), and exhibits a trigonal prism arrangement with Gd atoms occupying the prism corners and Ni atoms are positioned at the center of the prism. Early studies on the magnetic moments of Ni in GdNi concluded that Ni was non-magnetic, since it was expected that the Ni 3d shell can be fully occupied by electrons donated by trivalent Gd ions. However, later studies concluded Ni was magnetic, and the Gd moment was ferromagnetically aligned with Ni moments, effectively leading to an excess magnetic moment. The Gd moment was ferromagnetically aligned since it was expected that the Ni 3d shell can be fully occupied by electrons donated by trivalent Gd ions. Lent ion.

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II. EXPERIMENTS

GdNi polycrystalline samples were made by an arc-melting method using high purity constituent elements in argon gas atmosphere. The samples were subsequently annealed at 1173 K for 12 hours in an evacuated quartz tube. The samples were characterized by x-ray powder diffraction and were confirmed to be single phase. Magnetization measurements were carried out using a physical property measurement system (PPMS, Quantum Design, USA) and the results confirmed a ferrimagnetic T_C = 69 K, as reported earlier. In addition, the magnetization of GdNi tends to saturate above a critical field of about 1.5 Tesla and it does not show a spin-flop behavior.

XAS and XMCD measurements were carried out at Dragon Beamline (BL 11A) of the Taiwan Light Source. The beamline is a bending magnet beamline and the degree of circular polarization p = 0.8. The total electron yield method was used to measure XAS and XMCD across the Gd M_4,5-edge (3d-4f) and Ni L_2,3-edge (2p-3d) with circularly polarized light and an applied field of +/- 4 Tesla. The circularly polarized X-rays were incident normal to the sample surface and the X-ray propagation axis was parallel(+) or antiparallel(-) to the applied magnetic field (+/- 4 Tesla). We have used a clockwise circular polarization and a field of +4 Tesla and -4 Tesla to obtain the XAS spectrum as a sum of $\mu_+ + \mu_-$ and $\mu_0$ (where $\mu_0$ corresponds to an applied field perpendicular to the incident beam), and in the first approximation $\mu_0$ is taken to be $\mu_0 = (\mu_+ + \mu_-)$, as is standard procedure. Thus, XAS is proportional to the average of $\mu_+$ and $\mu_-$ spectra.

The photon energy was calibrated using a reference NiO sample and Dy metal sample. The total energy resolution at the Ni 2p - 3d edge was better than 0.2 eV for the XAS spectra, but for the XMCD spectra, due to the small XMCD signal expected of Ni in GdNi we used a larger slit size to enhance the spectral intensity at the cost of the energy resolution. The reduced energy resolution does not affect the sum rule analysis as the total spectral weight is conserved. For the XAS and XMCD measurements, the sample was polished ex-situ and immediately inserted into the fast entry chamber and pumped down to an ultra-high vacuum (UHV) of better than 8x10^-10 mbar. The sample was cooled using a liquid He flow type cryostat and the measurements were carried out at T = 25 K.

We monitored the stability of the Gd XMCD spectra, and the spectra were stable for about 8 hours at T = 25 K. Beyond 8 hours, the Gd XMCD signal got reduced a little. However, we could recover the XMCD signal after heating up the sample to T = 300 K and cooling again to T = 25 K. This indicated that the Gd XMCD signal was sensitive to adsorbed gases but did not change its
magnetic and electronic structure and the surface could be refreshed by warming up to T = 300 K. In order to calibrate the energy and confirm absence of oxidation, we simultaneously measured the Ni L-edge of NiO reference sample at T = 300 K in a chamber placed just before the main sample chamber. Similarly, we also measured O K-edge XAS of NiO reference sample and O K-edge energy range on the GdNi sample. Since the main peak of NiO Ni-L-edge is at 851.8 eV, which is about 1.2 eV below the main peak of Ni L-edge of GdNi at 853.0 eV and since we did not see any feature at 851.8 eV in GdNi sample, we confirmed absence of oxidation on GdNi surface. Further, we could quantify the intensity of O K-edge XAS intensity on sample surface to be less than 3 % compared to the NiO O K-edge signal. The measured spectra were corrected for the degree of circular polarization and for saturation effects in the TEY mode.

Valence band HAXPES ( $h\nu = 6500$ eV ) measurements were carried out at T = 80 K at the Taiwan beamline BL12XU of SPring-8 in Hyogo, Japan. The sample was cooled using a liquid N$_2$ flow-type cryostat. The overall energy resolution for HAXPES was 0.26 eV as estimated from a fit to the Fermi-edge of gold at T = 80 K, which was also used to calibrate the binding energy scale. For the HAXPES measurements, the sample was cleaved inside the UHV preparation chamber at a pressure of 5*10$^{-9}$ mbar and transferred to the main chamber at 8*10$^{-10}$ mbar for measurements. Although the probing depth of the HAXPES and TEY XAS are $\sim$100 Å and $\sim$25 Å respectively, since the surfaces were free of oxidation and the XMCD signal compared well with earlier studies on scraped samples, the data quality is good and represents the intrinsic electronic structure of GdNi, as is borne out by the results presented in the following.

III. RESULTS AND DISCUSSIONS

Fig. 1 shows the experimental and calculated Gd M$_{4,5}$-edge (3d-4f) XAS spectra of GdNi, measured at T = 25 K in the ferrimagnetic phase of GdNi. The experimental XAS spectrum consists of the spin-orbit split M$_5$ and M$_4$ levels separated by about 29 eV. The M$_5$ main peak is observed at an incident photon energy of 1182.3 eV with additional weak features at 1186.8 eV and 1189.6 eV. The M$_4$ features consist of two peaks of nearly equal intensity which are positioned at a photon energy of 1211.4 eV and 1213.0 eV, and a very weak feature is seen at 1217 eV. We used atomic multiplet calculations using the CTM4XAS program to confirm that Gd is trivalent in GdNi. In order to compare the experimental data with the calculations, we have subtracted out step-functions from the M$_5$ and M$_4$ edges convoluted with a Gaussian to mimic the transitions from the 3d core state to continuum states. The height of the step functions were set to a ratio of M$_5$:M$_4$ equal to 6:4, according to the J-value of the core hole state. Since the excitonic effect on the 4f states is at least 5 eV with respect to delocalised states, the step-function was applied from 10 eV above the main peaks.

In Fig. 1, we have plotted two types of calculated spectra: one with a symmetric Lorentzian broadening and the other with an asymmetric Fano broadening. While all the spectral features are reproduced in both the calculations, there are small differences between them and also small discrepancies compared to the experimental data. For the Lorentzian and Fano broadened spectra, the weak satellites of the M$_5$ edge are at photon energy positions slightly lower than the energies compared to the experimental. In contrast, for the M$_4$ edge, the satellite energy positions are in fair agreement, but the relative intensities of the multiplet tail at energies above 1215 photon energy are significantly lower in the Lorentzian broadened spectrum compared to the experiment. This is a general problem known from early work on M$_{4,5}$-edge XAS spectra of rare-earths and it was shown that a Fano broadening leads to a better match with the M$_4$ edge experimental spectra. As shown in the Fano broadened spectrum in Fig.1, it is clear that the multiplet tail intensities above 1215 eV indeed show an improvement compared to the Lorentzian broadened spectrum. While the results confirm the trivalent state of Gd, the finite intensity at high photon energies due to Fano broadening points to a breakdown of the sum rules used for calculating the spin and orbital moments of the Gd ion and are discussed later with the XMCD spectrum in Fig. 4.

In Fig.2, we show the experimental and calculated Ni L$_{2,3}$-edge (2p-3d) XAS spectrum of GdNi measured at 25 K. First of all, it is noted that the spectrum is quite unlike the XAS spectrum of Ni metal. The experimental spectrum consists of spin-orbit split L$_3$ and L$_2$ features separated by an energy of 17 eV. The L$_3$ main peak occurs at an incident photon energy of 853.0 eV and the L$_2$ main peak is observed at incident photon energy of 869.95 eV. The L$_3$ main peak has satellite features
at about 856.05 eV and 860.25 eV, while the L2 main peak has weak shoulders at 873.7 eV and 877.55 eV. We carried out calculations for the Ni 2p-3d XAS using a NiL₆ (L = ligand) cluster model calculation using the Quanity program.₁₆ We used a trigonal prism geometry with D₃d symmetry with a formal valency of divalent Ni ion. Although the real local structure of Ni is a regular trigonal prism corresponding to D₃h symmetry, we needed to use a lower D₃d symmetry to get the best match with the experimental data. This implies that the symmetry of the Ni trigonal prism has no mirror symmetry which is present in the D₃h point group. However, our model calculations reproduce all the features of the experimental data and can be considered as a starting point to understand the Ni L₂,₃-edge (2p-3d) XAS spectra.

The cluster model calculations were carried out by varying the electronic parameters in order to obtain a suitable match to the experimental spectrum. The best match was obtained for the Ni²⁺ configuration with the following electronic parameters: the charge transfer energy Δ = -0.6 eV, the on-site Coulomb energy U₆dd = 6.2 eV, the attractive core hole energy U₆pd = 10 eV. The value of U₆dd is typical for Ni containing compounds while U₆pd is somewhat larger than what is normally used, e.g. for NiO, U₆dd ~6.0 eV while U₆pd ~8.0 eV. The relatively large value of U₆dd compared to Δ classifies GdNi as a strongly correlated charge-transfer metal in the Zaanen-Sawatzky-Allen (ZSA) scheme which is used to characterize Mott-Hubbard vis-a-vis charge-transfer systems in general.₂₈ The ZSA picture is used to characterize materials in terms of the relative values of the on-site Coulomb energy U₆dd compared to the charge-transfer energy Δ scaled by the hybridization strength, which describes the nature of the lowest energy excitations. When U₆dd < Δ, the material is called a Mott-Hubbard system with a d–d type lowest energy excitation, while if U₆dd > Δ it is called a charge-transfer system, where Δ is the charge-transfer energy determining the lowest energy excitation. The charge transfer energy Δ is usually defined as the energy separation between the 3dⁿ configuration and the charge-transferred 3dⁿ⁺1L₃¹ state, where L₃¹ corresponds to one hole in ligand states. In our case, the ligand states are the Gd character nearest neighbor states of the Ni site which transfer electrons to the Ni site. It is noted here that the charge-transfer model of intermetallic alloys is independent of the definition of the charge-transfer metal in the ZSA picture. The trigonal prism geometry of NiL₆ causes a crystal field splitting with three states; a high energy doublet e′ₓᵧ, dₓᵧ, dₓz), an intermediate singlet aᵧg (dᵧz, dₓz), and a low energy doublet e′′ₓᵧ (dₓz, dₓᵧ) states. The aᵧg and e′ₓᵧ levels can be nearly degenerate or even inverted, depending on the valency as well as the spin-orbit interaction of the central metal ion Ni. The energy separation between e′ₓᵧ and aᵧg was taken to be Δ = 0.2 eV, while the energy separation between aᵧg and e′′ₓᵧ was taken to be D₀ᵧg = 1.0 eV and the hybridization strengths of the d levels with the ligand states were set to Vᵧag = -2.4 eV, Vᵧeg' = -0.65 eV, Vᵧeg'' = -2.0 eV. A Lorentzian broadening of 0.4 eV full-width at half maximum (FWHM) and an energy dependent Gaussian broadening, with 2.0 eV FWHM for all calculations. In contrast, spectrum A is the best match spectrum we could obtain for D₃h symmetry, as shown in Fig. 2.

We would like to clarify that we first tried many calculations using the D₃h symmetry, as shown in Fig. 3 (Spectra A to J). The best match spectrum obtained with D₃d symmetry shown in Fig. 2 is also plotted in Fig. 3 as spectrum K, but with lower broadening parameters to clarify the differences (In Fig. 3, Gaussian broadening is set to 1.5 eV FWHM and Lorentzian broadening is 0.2 eV FWHM for all calculations). In contrast, spectrum A is the best match spectrum we could obtain for D₃h symmetry, but it still fails to reproduce the experimental spectrum. In spite of an extensive search with many parameter sets with D₃h symmetry, we could not obtain a suitable calculated spectrum to match the experimental spectrum. In particular, when we got a suitable match for the L₃ edge, the L₂ edge did not match (see spectrum A in Fig. 3; electronic parameters used: U₆dd = 7.2 eV, U₆pd = 10.5 eV, Δ = 0.2 eV, Vᵧag = -1.732 eV, Vᵧeg' = -0.5 eV, Vᵧeg'' = -4 eV). In contrast, if the main peaks of the L₃ and L₂ edges matched the experiment, the intensities of the satellite peaks were too low (see spectra E to J in Fig. 3).

In the following, we briefly describe our attempts to match with the experimental spectrum using D₃h symmetry. Starting with the parameters of spectrum A, we changed U₆dd and U₆pd to the same value as used for spectrum K. We obtained spectrum B in which the peaks b, c, d and e got slightly shifted and the intensity of c increased, but the intensity of peak d got reduced. Spectra

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**FIG. 2.** The experimental Ni L₂,₃-edge (2p-3d) X-ray absorption spectra of GdNi at T = 25 K compared with a calculated spectrum obtained using a metal-ligand cluster model calculation.
C and D were obtained by only changing \( \Delta \) to -0.2 eV and 0.6 eV, respectively, keeping all other parameters as for spectrum B. The intensity of peak b and f decreased, the intensity of peak d increased, and the positions of peak b, c, and f got slightly shifted. Then, we changed the hybridization energy \( V_{\text{eg}} \) to -2 eV and -2.4 eV to obtain spectra E and F. We get a small new feature f, while the intensities of features b, e, and f are very weak. Also, the intensity of peak c decreased, and the intensity of peak d increased. All the peaks were slightly shifted to higher energy. In spectra G, H, only hybridization energy \( V_{\text{eg}} \) was changed to 0 eV and 0.65 eV but the spectra hardly changed. Finally, the spectra I, J were obtained by changing hybridization energy \( V_{\text{eg}} \) to -3 eV and -2 eV, keeping all the other parameters fixed. The four spectra (G, H, I, J) are very similar. Thus, all the parameters of spectrum J (D_{2h}) and K (D_{3d}) are the same, but clearly spectrum K matches better with the experiment. Hence we felt using D_{3d} symmetry instead of D_{2h} symmetry, we could obtain a suitable match for energy positions and intensities of the L_3 and L_2 edges, as well as the satellites seen in the experimental spectrum. The calculated spectrum K corresponds to a Ni 3d electron count of 8.57 in the ground state. This indicates that the Ni 3d band is not fully occupied. In comparison, it is noted that from a magnetic study of a series of amorphous binary (GdFe, GdCo and GdNi) and ternary alloys of the type Gd_{0.2}(M1,M2_{1-0}) with M1, M2 = Fe, Co and Ni and x \( \sim \)0.9 to \( \sim \)0.2, it was concluded that GdNi corresponds to an effective one electron transfer from Gd to Ni\(^{20}\). This would correspond to the total number of 9 d electrons in GdNi i.e. 3d\(^8\)4s\(^2\) configuration, starting with 3d\(^8\)4s\(^2\) for Ni metal. Our results indicate a lower estimate of 8.57 3d-electrons in the ground state in a configuration interaction picture, starting with a formal Ni\(^{2+}\) divalent configuration of 3d\(^8\), and admixture from charge transferred states of the type 3d\(^9\)L\(^{-}\) and 3d\(^{10}\)L\(^{-}\), where L\(^{-}\) corresponds to a hole in the ligand states. As we show in the following, this results in a small magnetic moment for Ni sites, with slightly different values compared to the results reported by Yano et al.\(^{20}\). However, in the study of Yano et al., calculations for the XAS Ni 2p-3d and XMCD spectra were not reported. Thus, our results provide a direct and quantitative measure of the d electron count of Ni in GdNi.

In Fig. 4, we show the Gd M\(_{4,5}\)-edge XMCD spectrum measured at \( T = 25 \) K, using circularly polarized X-rays and an applied field of +/- 4 Tesla. The difference spectrum between the +4 Tesla and -4 Tesla spectra shows a clear XMCD signal as seen in Fig. 4. The spectral features are very similar to earlier XMCD spectra of GdNi\(^{20}\) as well as other Gd containing materials like GdNi\(_3\), Ce\(_{0.5}\)Gd\(_{0.5}\)Ni\(_3\), the metallacrown materials GdNi\(_8\), etc. The similarity of the XMCD spectra in different materials indicates consistency with a localized picture for the Gd\(^{3+}\) ions. We have used the CTM4XAS program with the same electronic parameters as for the calculated XAS spectrum shown in Fig. 1 to also calculate the XMCD spectrum. Here again, we have cal-

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**TABLE I. Table of electronic parameters for calculated spectra shown in Fig.3.** Error bars for each electronic parameter which individually gives a d-electron count variation of about +/- 0.02, and acceptable changes in spectral shape are listed.

| Spectrum | \( \Delta \) | \( U_{dd} \) | \( U_{pd} \) | \( V_{\text{eg}} \) | \( V_{\text{eg}'} \) | \( V_{\text{eg}''} \) |
|----------|-----------|-----------|-----------|-----------------|-----------------|-----------------|
| A        | 0.2       | 7.2       | 10.5      | -1.732          | -0.5            | -4.0            |
| B        | 0.2       | 6.2       | 10.0      | -1.732          | -0.5            | -4.0            |
| C        | -0.2      | 6.2       | 10.0      | -1.732          | -0.5            | -4.0            |
| D        | -0.6      | 6.2       | 10.0      | -1.732          | -0.5            | -4.0            |
| E        | -0.6      | 6.2       | 10.0      | -2.0            | -0.5            | -4.0            |
| F        | -0.6      | 6.2       | 10.0      | -2.4            | -0.5            | -4.0            |
| G        | -0.6      | 6.2       | 10.0      | -2.4            | 0.0             | -4.0            |
| H        | -0.6      | 6.2       | 10.0      | -2.4            | 0.65            | -4.0            |
| I        | -0.6      | 6.2       | 10.0      | -2.4            | 0.65            | -4.0            |
| J        | -0.6      | 6.2       | 10.0      | -2.4            | 0.65            | -2.0            |
| K        | -0.6      | 6.2       | 10.0      | -2.4            | 0.65            | -2.0            |

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FIG. 3. The comparison of Ni L\(_{2,3}\)-edge XAS spectra obtained using D\(_{3d}\) symmetry (spectra A-J) for different electronic parameters as listed in Table 1 compared with the best match obtained using D\(_{3d}\) symmetry.
The calculated XMCD spectra with a symmetric Lorentzian broadening and an asymmetric Fano broadening. The calculated XMCD spectra for both cases are very similar indicating that although the XAS spectrum was better explained by the Fano broadened spectrum, the XMCD spectrum is not sensitive to the type of broadening used. The calculated XMCD spectra correspond to a ground state configuration of $S = 7/2$ ($S_z = -3.465 \mu_B$) and $L = 0$ ($L_z = -0.0345 \mu_B$). $L_z$ is not exactly zero due to a combination of $4f^4f$ multiplet interactions and the $4f$ spin-orbit coupling. However, if we use a Fano broadening to simulate the XAS and XMCD spectra, this leads to a small dip before the $M_4$ edge and finite intensity at photon energies far above the $M_4$ edge in XAS and XMCD spectra. This means that we cannot set the XMCD intensity to zero before and after the edge. Further, the integral of the XAS and XMCD spectra do not saturate at high photon energies. In turn, this implies that the orbital magnetic moment, $m_o$, cannot be 0 even for Gd$^{3+}$ ions with $L = 0$, leading to an effective breakdown of the sum rule analysis. It is interesting to test this proposition quantitatively on other rare-earth systems and future work in this direction would be valuable. We have nonetheless carried out a sum rule analysis using the atomic multiplet calculation results and compared it with the experimental XAS and XMCD data. We first normalized the calculated XAS spectrum with the experimental spectrum. Using the same normalization factor for the theoretical XMCD intensity results in a higher intensity of the calculated spectrum compared to the experimental XMCD spectrum. The atomic calculation results need to be reduced to 92.6% in order to match the experimental XMCD spectrum. Based on this, the experimental estimate of an effective spin magnetic moment $m_{s,eff} = 2S_z, eff = 6.42 \pm 0.1 \mu_B$, i.e. it is reduced compared to the $7 \mu_B$ corresponding to the $S = 7/2$ ground state. Similarly, the effective orbital magnetic moment was reduced to $m_{o,eff} = 0.032 \pm 0.01 \mu_B$. We attribute the reduced effective spin moment $m_{s,eff}$ to the role of crystal field effects, finite temperature of the measurement as well as the fact that we needed a Fano type broadening to better explain our experimental data for the multiplet tail intensities above 1215 eV (Fig. 1). It is noted that in a recent study on in-situ deposited amorphous thin films of Co$_x$Gd$_{1-x}$, a reduction of Gd spin moment with $m_s = 3.8 \mu_B$ was reported.

FIG. 4. The experimental Gd $M_{4,5}$-edge (3d-4f) XMCD spectra of GdNi at $T = 25$ K compared with atomic multiplet calculations using two different types of broadenings: a Lorentzian broadening and a Fano broadening. The spectra are shifted along the $y$-axis for clarity.

FIG. 5. The experimental Ni $L_{2,3}$-edge (2p-3d) X-ray magnetic circular dichroism spectra of GdNi at $T = 25$ K compared with calculated spectrum obtained using a metal-ligand cluster model calculation. The spectra are shifted along the $y$-axis for clarity.
than previously estimated values of $m_s = 0.09 \mu_B$ and $m_o = 0.014 \mu_B$.\textsuperscript{19} It is also noted that Yano et al. reported a ratio $m_o/m_s = 0.16$\textsuperscript{20} and we obtain a ratio of $m_o/m_s = 0.11$.

IV. CONCLUSION

In conclusion, we have carried out XAS and XMCD of GdNi in the ferrimagnetic phase at $T = 25$ K. The Gd $M_{4,5}$-edge and Ni $L_{2,3}$-edge XAS and XMCD spectra could be analyzed using atomic multiplet and cluster model calculations, respectively. The Ni $L_{2,3}$-edge XAS and XMCD experimental spectra are fairly consistent with the cluster model calculations carried out for the D3d local symmetry. We could quantify the hole density of the Ni 3d states as well as the magnetic moments associated with the Ni 3d states in GdNi. We also confirmed the trivalency of Gd ions and consistency of the Gd XMCD with a $S = 7/2$ and $L = 0$ ground state. The HAXPES valence band spectrum shows a Ni 3d character sharp peak at the Fermi level, consistent with a partially filled 3d band, while the Gd 4f states are at high binding energies away from the Fermi level. The results indicate that the Ni 3d band is not fully occupied and contradicts the charge-transfer model for rare-earth based alloys.

![Graph (a) and (b)](image-url)
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