PHYSICAL REVIEW B VOLUME 37, NUMBER 14 15 MAY 1988-I

Interpretation of photoemission and bremsstrahlung isochromat spectra of uranium compounds

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(Received 9 October 1987)

Bremsstrahlung isochromat (BIS) and U $4f$ core-level photoemission (PE) spectra of UPt and UPt_5 are presented and compared with corresponding data—including U $5f$ valence-band PE spectra—of UBe_{13}, as well as with the results of band-structure calculations. The shapes of the BIS, U $5f$, and U $4f$ PE spectra are consistently explained in terms of two differently screened final states, namely an f-screened main peak reflecting the delocalized $5f$ part of the electronic ground state, and a poorly screened satellite increasing in intensity with decreasing $5f$ hybridization. The considerably higher relative intensity of the f-screened main peak in $5f$ PE as compared to BIS spectra is readily explained on the basis of the degeneracies of the relevant $5f$ screening orbitals in U compounds. The positions of the poorly screened satellites relative to the f-screened main peaks in BIS spectra are found to be related to those of the Pr $4f^3$ BIS multiplets in homologous Pr compounds, i.e., they reflect chemical shifts. It is also realized that the relative intensities of these BIS satellites follow those of the satellite peaks in U $4f$ core-level PE spectra.

I. INTRODUCTION

Recently, the discovery of the heavy-fermion superconductors $CeCu_2Si_2$ (Ref. 1), UPt_3 (Ref. 2), and UBe_{13} (Ref. 3) has renewed interest in the electronic properties of Ce and particularly of U compounds, with a considerable amount of theoretical[4,5] and experimental[6–8] work having already been performed. The peculiar properties of these materials are dominated by the existence of partly occupied f states, which exhibit an intermediate character between localized and bandlike behavior depending on f-f overlap and valence-band hybridization. This intermediate character of the $5f$ electrons leads to strong many-body effects in high-energy spectra, e.g., in photoemission (PE) and bremsstrahlung isochromat spectra (BIS), which have been studied extensively for Ce systems.[9] In most intermetallic compounds, Ce exhibits a $4f$ ground-state configuration close to one, i.e., addition or emission of an f electron in BIS or PE, respectively, will lead to $4f^2$ or $4f^0$ final states, separated in energy from each other by the Coulomb correlation energy, $U \simeq 5$ eV.[10] An increase of $4f$ hybridization in the so-called α-like Ce materials, however, is known to cause an additional $4f^1$ final state very close to E_F, reflecting a $4f$-screening effect in the final state.[11] This peak can be well understood on the basis of the Anderson Hamiltonian[12] or it may be related to a Kondo resonance.[13]

U systems represent to some extent an extension of the "Ce problem" with respect to stronger hybridization, larger $5f$ ground-state occupancy, and reduced Coulomb energies. Instead of separated peaks as in the Ce case, $5f$ PE and BIS spectra of U compounds generally exhibit broad structures with a finite density of states at E_F that are found to be much wider than expected from one-electron band-structure calculations.[5] Since a treatment of these systems on the basis of the Anderson Hamiltonian has not yet been achieved, mostly due to the large ground state $5f$ occupancy (close to 3), it appears reasonable to describe these spectra approximately by the superposition of well-screened (by f electrons) and poorly screened (by nonlocalized valence electrons) final states.[14,15] In such a picture, the f-screened peak corresponds in shape and position to the partial density of $5f$ states (PDOS) resulting from band-structure calculations, whereas the poorly screened satellite represents a localized $5f^n$ final-state multiplet, where n is either larger (BIS) or smaller (PE) than the ground-state $5f$ occupancy. Recently, such a model was successfully applied to BIS spectra of the $UNi_{5-x}Cu_x$ series of compounds[14] as well as to U $5f$ PE spectra of uranium-based heavy-fermion systems, in particular of UBe_{13}.[16] The relative intensities of the f-screened and poorly screened components could be related to the degree of $5f$ hybridization, but the positions of the d-screened satellites relative to the main peaks were not discussed, and neither was the relation between satellite intensities in U $5f$ PE and BIS spectra.

In the present publication we show that the poorly screened satellites may be treated in analogy to the localized $4f^n$ multiplets of homologous rare-earth (R) compounds. The arguments are based on new BIS data for UPt and UPt_5, as well as for the homologous Y compounds, and a comparison with previously published work on UBe_{13} and the homologous Pr compounds. We show that for all three U compounds the shape of the $5f$ emission can be described by superposition of the $5f$ PDOS with a poorly screened satellite shifting in energy in a similar way as the localized $4f^3$ multiplet in the homologous Pr compounds. From this fact and from comparison with data for α-U metal and UO_2, we conclude, in deviation from previous work, that the poorly screened BIS satellite corresponds to a $5f^3$ final-state multiplet. The presence of a corresponding poorly screened $5f^2$ final state in U $5f$ PE valence-band spectra is discussed, and its much weaker intensity relative to the BIS satellite is quantitatively explained on the basis of the degeneracies of f-screening channels in U $5f$ PE and BIS processes. Satellite structures in U $4f$ core-level PE spectra are also interpreted on the basis of poorly screened final states, and their relative intensities are found to be correlated to those of the poorly screened final-state satellites in BIS.

II. EXPERIMENTAL DETAILS

The U compounds studied were prepared by arc melting under an Ar atmosphere, and their single-phase compositions were checked by x-ray diffraction. UPt and YPt crystallize in the orthorhombic CrB structure, UPt_5 has the $AuBe_5$, and YPt_5 the $SmPt_5$ structure. The measurements were performed with a home-built BIS spectrometer, tuned to 1486.6 eV photon energy, with a total-system resolution of 0.7 eV. The PE spectra were taken with nonmonochromatized Al $K\alpha$ radiation resulting in a total-system resolution of 1.4 eV. To avoid oxygen contamination in the experimental chamber (with a base pressure of 1×10^{-10} Torr), the samples were repeatedly cleaned *in situ* by scraping with a diamond file about every 5 min.

III. RESULTS AND DISCUSSION

A. Structure of BIS spectra of UPt, UPt_5, and UBe_{13}

Figure 1 shows BIS spectra of UPt and UPt_5 and—for reasons of comparison—also of the corresponding homologous Y compounds. Apart from the $5f$ electrons, the valence shell of Y is isoelectronic with that of a trivalent actinide element. Therefore, the Y spectra may be used in estimating the d-derived spectral contributions of the valence bands in the U-based compounds. As can be seen from Fig. 1, the valence bands of both YPt and YPt_5 are rather flat. A small peak at the Fermi level (E_F) in YPt_5 stems from unoccupied Pt $5d$ states and is characteristic for RPt_5 compounds.[17] In YPt, on the other hand, the Pt $5d$ band is filled and well removed from E_F, as is also known from PE investigations of ThPt and UPt.[18] Therefore, the flat double-peaked structure in YPt arises from transitions into unoccupied Y $4d$ bands, which—in addition to a 20% narrowing—are shifted by 0.7 eV to higher energy relative to the analogous structure in the BIS spectrum of Y metal.[19] This causes a predominantly s-like density of states at E_F in YPt.

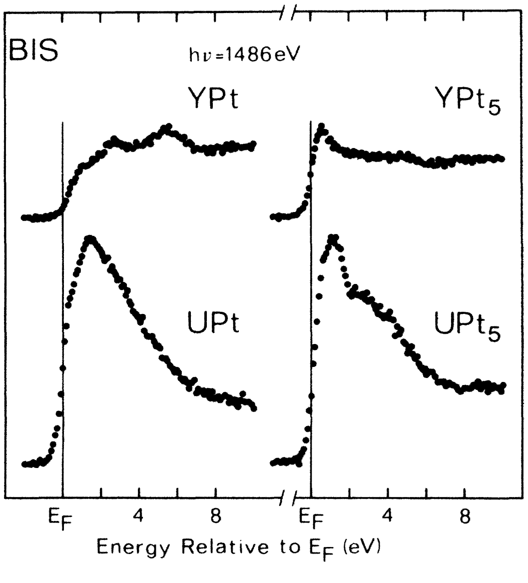

FIG. 1. BIS spectra of UPt and UPt_5, and—for comparison—also of YPt and YPt_5. The relative intensities of the individual spectra are arbitrary.

As is evident from a comparison with these Y-based compounds, the BIS spectra of UPt and UPt_5 are dominated by transitions into unoccupied U $5f$ states. Taking band-structure calculations for α-U metal[20] and UPt_3 (Ref. 4) as a reference, the widths of the $5f$-derived BIS peaks are found to be more than twice as large as expected from theory; this clearly shows that electron correlation effects in the final state are important in these U systems. A closer inspection of Fig. 1 shows that the BIS spectrum of UPt_5 is very similar to the one previously observed for UNi_5;[14] it obviously consists of two components, with the peak close to E_F corresponding in width and position to the theoretically expected $5f$ band. In contrast to that, the UPt spectrum exhibits only a single broad structure resembling in this respect the BIS spectrum of UCu_5.[14] The similarities between the BIS spectra of UPt_5 and UNi_5 on one side and those of UPt and UCu_5 on the other side may not be considered accidental: Since Pt and Ni belong to the same group of the Periodic Table, the behavior of U in dilute compounds with these elements is expected to be similar. On the other hand, Pt resembles a noble metal in UPt due to complete filling of the Pt $5d$ band, which explains the similarities of the BIS spectra of UPt and UCu_5 on the basis of their valence-electron densities of states.

Since in both cases the widths of the $5f$-derived BIS peaks are much larger than expected from theoretical $5f$ bandwidths, the shapes of both spectra may be described by a superposition of signals from two different final states, namely a well-screened peak at E_F (screened by f electrons) and a poorly-screened peak at higher energies (screened by nonlocalized valence electrons). The former peak corresponds in width and position to the $5f$ PDOS resulting from single-particle band-structure calculations, while the poorly screened peak is related to the multiplet of a localized $5f^n$ final state. From a comparison with calculated PE multiplets,[21] Hillebrecht *et al.* assigned a $5f^4$ configuration to the localized BIS peaks in $UNi_{5-x}Cu_x$,[14] but we shall show further below that an assignment of $5f^3$ yields better results. Independent of the exact value of n, the shapes of the poorly screened $5f^n$ multiplets should be identical for all U compounds. Since the widths of the $5f$ bands are expected to be rather similar in different U compounds, the variations in the overall shapes of the BIS spectra must be mainly caused by changes in relative intensity and position of the two components. An increase in relative intensity of the poorly screened peak reflects an increase in $5f$ localization and may be correlated with a decrease in $5f$ hybridization or f-f overlap. On the other hand, variations in energy separation between the two components may reflect changes in Coulomb correlation energy and/or changes in the ground-state $5f$ occupancy. Since for purely bandlike states the $5f$ occupancies of the initial and final state are expected to be identical, the difference between the ground-state $5f$ occupancy and the multiplet order n in the BIS spectrum should be a measure for the Coulomb repulsion between the two different final states. Unfortunately, Coulomb correlation energies and $5f$ occupancies represent quantities which are not readily obtainable for these systems, making a straightforward analysis of the BIS spectra along these lines infeasible.

On the other hand, one might treat the poorly screened components in BIS spectra of U compounds in the same way as the fully localized $4f^n$ final-state multiplets of rare-earth (R) materials. In the latter case, the energy position of the $4f$ multiplet is known to reflect the stability of a certain $4f^n$ configuration. Upon alloying or compound formation, changes in the chemical environment alter the stability of the final state leading to so-called chemical shifts in the $4f$-related features of the spectra.[22] In this respect, the Pr $4f^3$ BIS multiplet is known to shift by 1.6 eV to higher energies when going from pure Pr metal to the $PrPt_5$ compound, whereas a smaller chemical shift of only 1.3 eV has been observed between Pr and PrPt.[17] Assuming an analogous behavior for a localized U $5f^3$ multiplet in corresponding U compounds, a shift of the poorly screened (localized U $5f^3$) component by $\simeq 0.3$ eV towards E_F is expected when going from UPt_5 to UPt.

In order to check the validity of this model, we have decomposed the BIS spectra of both compounds, UPt_5 and UPt, into f-screened and poorly screened components. The f-screened ("bandlike") component was idealized by a symmetric Gaussian. The expected ground-state $5f$ occupancy of $n \simeq 3$ was taken into account by pinning the energy position of this Gaussian in such a way to E_F that $\frac{3}{14}$ of its area is situated below E_F. The poorly screened component was described by an asymmetrical Gaussian, with a shape as resulting from the best least-squares fit of the UPt_5 spectrum; in this fit, a steplike background was assumed to describe spectral contributions from the valence band. In order to account for finite experimental resolution, the generated spectra were convoluted with a Gaussian resolution function.

The results of the least-squares fits of the BIS spectra are shown in the right upper part of Fig. 2, where the signals from the two differently screened final states are distinguished by differently shaded subspectra. In the case of UPt_5, we obtain for the bandlike (f-screened) component a full width at half maximum (FWHM) of 1.85 eV, which agrees well with the $5f$ bandwidth calculated for UPt_3.[4] For the localized (poorly screened) component, we obtain a FWHM of 3.0 eV, positioned at 2.9 eV above E_F. This position coincides roughly with the one of the $5f^3$ multiplet in tetravalent UO_2 (with a rather localized $5f^2$ ground state), rendering an interpretation of this component as a $5f^3$ multiplet very likely. The total splitting of the $5f^3$ multiplet is known from UV absorption spectra to be $\simeq 2.7$ eV,[20,23] which is in excellent agreement with the result of our fit analysis, thus supporting the given assignment. Further support comes from the fact, that—by applying the concept of chemical shifts—the $5f^3$ configuration in U metal would be expected at 1.3 eV above E_F. In this case, the poorly screened component would almost coincide in energy with the position of the $5f$ band, and since the $5f$ occupancy in U metal amounts to $n \simeq 3$, the same $5f$ occupancy should also be relevant to the poorly screened final-state multiplet.

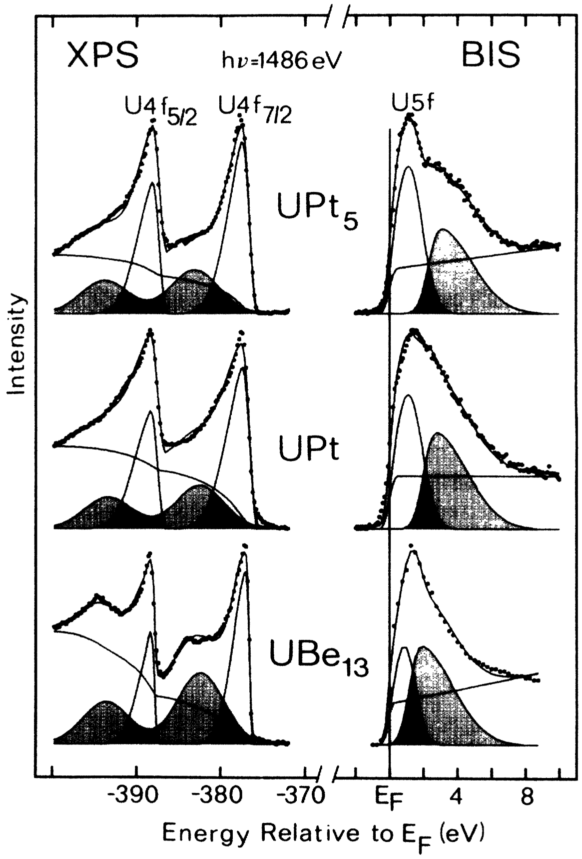

FIG. 2. U $4f$ core-level PE spectra (XPS) (on left side) and BIS spectra (on right side) of UPt_5, UPt, and UBe_{13}. The individual spectra are decomposed each into two final-state components reflecting the bandlike part of the $5f$ ground state (light-shaded subspectra) and poorly screened satellites with localized $5f$ character (dark-shaded subspectra). The data for UBe_{13} were taken from the work of Wuilloud *et al.*[8] Note the different spectrometer resolutions in case of the UPt and UPt_5 spectra on one side and the UBe_{13} spectra on the other side; also note the different energy scales on the abscissa of the XPS and BIS spectra.

Assuming a comparable bandwidth for UPt and UPt_5, we have fitted the BIS spectrum of UPt with nearly the same parameters as obtained from the analysis of the UPt_5 spectrum. Only the energy position of the poorly screened component was shifted to lower energies by 0.3 eV. Using only the intensities of the two components and the shape of the background as adjustable parameters, an excellent fit was obtained by increasing the relative intensity of the poorly screened peak by a factor of 1.2 as compared to UPt_5 (see Table I). This points to a higher $5f$ lo-

TABLE I. Ratio of intensities of poorly screened satellites to those of f-screened main components in the U $5f$ BIS and U $4f$ PE spectra of the three U compounds analyzed.

	U $5f$ BIS	U $4f$ PE
UPt_5	0.93 ± 0.03	0.58 ± 0.05
UPt	1.15 ± 0.10	0.57 ± 0.05
UBe_{13}	2.04 ± 0.20	1.19 ± 0.10

calization in UPt, as expected in view of the filled Pt $5d$ states in this compound, which should lead to a decrease in f-d hybridization relative to UPt_5.

This good agreement between our model and the BIS spectra of UPt and UPt_5 could be fortuitous, due to the small shift of the poorly screened components between UPt_5 and UPt. A better test to check the applicability of our model for the interpretation of U spectra based on chemical shifts from homologous Pr compounds is provided by compounds of U with *sp* metals, since chemical shifts of compounds with *sp* metals are generally smaller by $\simeq 1$ eV than those of transition-metal compounds.[22] Therefore the largest deviations from the $5f$-derived shape of the BIS spectrum of UPt_5 are expected for compounds like UAl_2 or UBe_{13}. Indeed, triangular-shaped structures have been observed in the BIS spectra of these compounds, which were found to be much broader than those expected on the basis of calculated one-particle bandwidths.[7,8] We have therefore performed the analogous analysis of the BIS spectrum of UBe_{13}, which was taken from the literature.[8] The results of this analysis are presented in the right lower part of Fig. 2. In the least-squares fit, only the width of the f-screened component, the energy position of the poorly screened component, the relative intensities of these two components, and the shape of the background were used as adjustable parameters. An excellent fit is obtained (i) by shifting the position of the poorly screened peak by 1.1 eV to lower energies as compared to UPt_5, (ii) by increasing its relative intensity by a factor of 2.2, and (iii) by decreasing the FWHM of the f-screened component to 1.4 eV (see Table I). The resulting width of 1.4 eV is slightly larger than the calculated bandwidth of 0.9 eV,[5] but the expected decrease of the bandwidth as compared to UPt_5 is well reproduced. Unfortunately, no BIS data are available for RBe_{13} compounds, so that a value for the chemical shift is not known. However, other *sp*-band metal compounds, like $CeAl_2$ (Ref. 17) and $GdAl_2$ (Ref. 22) exhibit shifts of the order of 0.5 eV. This value also agrees with the observed trivalency of Yb in $YbBe_{13}$:[24] Since the stability of the divalent $4f^{14}$ configuration amounts to $\simeq 0.5$ eV in Yb metal, a chemical shift of at least that magnitude is required to stabilize the trivalent $4f^{13}$ configuration in $YbBe_{13}$. Thus, adopting a value of 0.5 eV for the chemical shift of the $4f$ multiplet in RBe_{13} compounds, the poorly screened $5f^3$ component in UBe_{13} is expected to be 1.1 eV closer to E_F as compared to UPt_5, in excellent agreement with the result of our analysis. The large intensity of the poorly screened BIS peak in UBe_{13} reflects a strong enhancement of $5f$ localization in this compound as compared to UPt_5, which also agrees well with the observed narrowing of the $5f$ band.

B. Relationship between U 5*f* BIS and PE spectra

A splitting of the U-5f PE spectrum into f-screened and poorly screened components must be expected from the analogy between the BIS and PE processes, based on time-reversal arguments. In fact, the presence of a 2-eV satellite in the resonant PE spectrum of α-U metal was previously interpreted in terms of a poorly screened $5f$ state,[25] but it could be shown later that this structure is related to emission from the U $6d$-$7s$ valence band.[26] Most recently, the existence of a 1-eV satellite has been established in the U $5f$ PE spectrum of UBe_{13} from a careful comparison between PE data and the results of band-structure calculations.[16] Figure 3 shows the analysis of the U $5f$ PE spectrum of UBe_{13} taken from Ref. 16; in addition, our analysis of the BIS spectrum of this compound is reproduced. Note that in both spectra only the U $5f$-derived signals are shown after complete background subtraction. Energy position, width, and intensity of this 1-eV PE satellite are found to be in excellent agreement with predictions based on our model. A hypothetical poorly screened PE component should correspond to a localized $5f^2$ configuration with a net multiplet splitting of $\simeq 1$ eV,[21] in good agreement with the obtained FWHM of the satellite. From the position of the localized $5f^3$ configuration in the BIS spectrum and assuming a Coulomb correlation energy of 5 eV between the $5f^3$ and the $5f^1$ configurations,[20] a binding energy of $\simeq 1$ eV is obtained for the $5f^2$ configuration, in good agreement with experimental observation. Finally, assuming the same transition matrix elements for f-

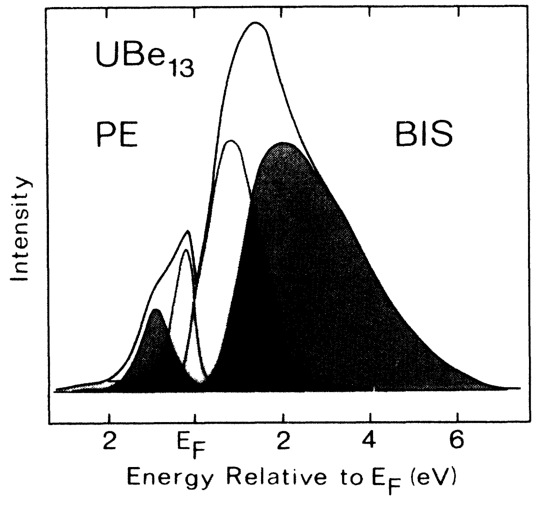

FIG. 3. Results of a consistent analysis of the U $5f$ PE and BIS spectra of UBe_{13}. In both spectra, the backgrounds have been subtracted and only the U $5f$ signals are shown for simplicity. The analysis of the U $5f$ PE spectrum is taken from Ref. 16. The light-shaded subspectra represent the f-screened bandlike ground state, while the dark-shaded subspectra give the poorly screened localized $5f$ satellites. Note the much higher relative intensity of the satellite in the BIS spectrum.

screening in BIS and PE, the relative intensity of the *f*-screened peak should be proportional to the degeneracy of the *f*-like screening channels. In PE, this degeneracy is given by the number of unoccupied $5f$ states (11 in the case of trivalent U compounds), in BIS by the number of occupied $5f$ states (3 in the present case); it is therefore by a factor of $\simeq 4$ larger in PE as compared to BIS. Our fit analysis shows that the intensity of the poorly-screened peak in the BIS spectrum of UBe_{13} is about twice that of the *f*-screened component. Therefore, the corresponding peak in the PE spectrum should be only half as intense as the *f*-screened peak, which is indeed the case (see Fig. 3).

C. Comparison with structure of U 4*f* core-level PE spectra

As shown in the left part of Fig. 2, similar satellite structures are also observed in the PE spectra of the U $4f$ core-level region, which may be correlated in an analogous way with the degree of localization of the $5f$ states.[27] In this case, arguing on the basis of the $(Z+1)$ approximation, $5f$ states are lowered by the potential of the photohole and may or may not be occupied by an extra *f*-like screening electron in the PE process, depending on the degree of $5f$ hybridization. Within this model, the strong main lines observed in the spectra (see Fig. 2, left side) correspond to an *f*-screened (well-screened) final state, whereas the poorly screened state gives rise to broad satellites at 5–7 eV higher binding energy. The apparently different shapes of the U $4f_{5/2}$ and U $4f_{7/2}$ satellites, as well as the substructures visible for the latter components, reflect multiplet splitting effects and point to an enhanced $5f$ localization in this final state. To achieve a rough quantitative estimate for the relative intensities of these satellites, we have performed a least-squares fit analysis of the data by a superposition of two spin-orbit-split doublets with an integral background, the latter describing inelastic scattering processes. Since the line shapes are expected to be affected by multiplet-splitting and many-body effects, they could not be described in a simple analytical form; they were therefore approximated by asymmetric Gaussian lines. The resulting relative intensities of the satellites are also summarized in Table I. Quite similar to the BIS case, no big differences were found between the satellite intensities of UPt and UPt_5, while an increase in satellite intensity by a factor of 2 was observed for UBe_{13}. Even though a one-to-one relationship between BIS and core-level PE spectra cannot be expected due to the different Hamiltonians involved, the general trend in the relative intensities of the satellites is well reproduced. This observation again strongly supports our interpretation of the BIS spectra of U compounds in terms of well-screened (*f*-screened) and poorly screened final states.

IV. CONCLUSIONS AND OUTLOOK

The successful attempt of a unified description of PE and BIS spectra of uranium compounds, presented in this paper, should greatly help in extracting fruitful electronic-structure information from a wealth of existing experimental data on these materials. These spectra were shown to contain both well screened (by *f* electrons) and poorly screened (by nonlocalized valence electrons) components, with relative intensities depending on the degree of $5f$ localization. The much higher relative intensities of the *f*-screened components found in $5f$ PE spectra as compared to BIS spectra are quantitatively explained on the basis of the degeneracies of the *f*-like screening channels. The *f*-screened spectral components are directly related to the $5f$ partial density of states of the electronic ground state, while the poorly screened satellites are found to correspond to rather localized final states, $5f^2$ in $5f$ PE and $5f^3$ in $5f$-BIS spectra. Correspondingly, these localized spectral features are found to exhibit chemical shifts between different uranium compounds, in analogy with the chemical shifts of homologous compounds of Pr. In this way, the proposed model leads to a consistent picture of the hitherto puzzling line shapes reported for PE and BIS spectra of the valence-band region of uranium compounds.

We would like to add at this point that the given interpretation of the spectral components close to the Fermi level in terms of well-screened peaks, representing the partial density of $5f$ states, could be questioned on the basis of recent experimental results for the dilute U_xY_{1-x} system.[28] From U $5f$ PE spectra, which were found to be essentially independent of x down to dilutions of $x=0.02$, it was concluded that single-site effects dominate the spectral features. However, even in concentrated U systems, $5f$ bands are known to be predominantly caused by $5f$-ligand hybridization and not by direct $5f$-$5f$ overlap,[29] with the former being rather insensitive to dilutions of the kind described. The observations in Ref. 28 are therefore not excluding contributions of the partial density of $5f$ states to the observed PE spectra, as discussed in the present paper.

We would also like to point out that the presented unified description of PE and BIS spectra is not readily solving the general difficulties encountered in understanding the electronic structure of uranium-based heavy-fermion systems, which were recently summarized in Ref. 30. Both single-particle band calculations and electron-spectroscopic results are not reproducing the high densities of state at the Fermi level, which seem to be necessary in order to account for the extreme mass enhancements observed in specific-heat measurements. From the experimental point of view, a possible explanation of this puzzle could be that states with large effective masses are more affected by final-state effects, contributing therefore predominantly to the poorly screened peaks, while the ordinary band states, with smaller effective masses, contribute to the well-screened peaks. More theoretical work in this direction is certainly highly desirable. It can also not be excluded at present, that intense narrow density-of-states features close to E_F are not observed because of the rather limited experimental resolution still available ($\simeq 0.1$ eV in resonant PE, and $\simeq 0.5$ eV in XPS and BIS experiments). As shown recently, a resolution of at least 20 meV is required in order to obtain even faint signals from Kondo resonances in Ce systems.[31] Even though such a resolution is presently beyond the possibilities of inverse PE experiments, it would be of appreciable interest to perform high-resolution PE studies in the vacuum-ultraviolet photon-energy range on UBe_{13} and UAl_2.

ACKNOWLEDGMENT

This work was supported by the Sonderforschungsbereich-6 of the Deutsche Forschungsgemeinschaft (Teilprojekt A1).

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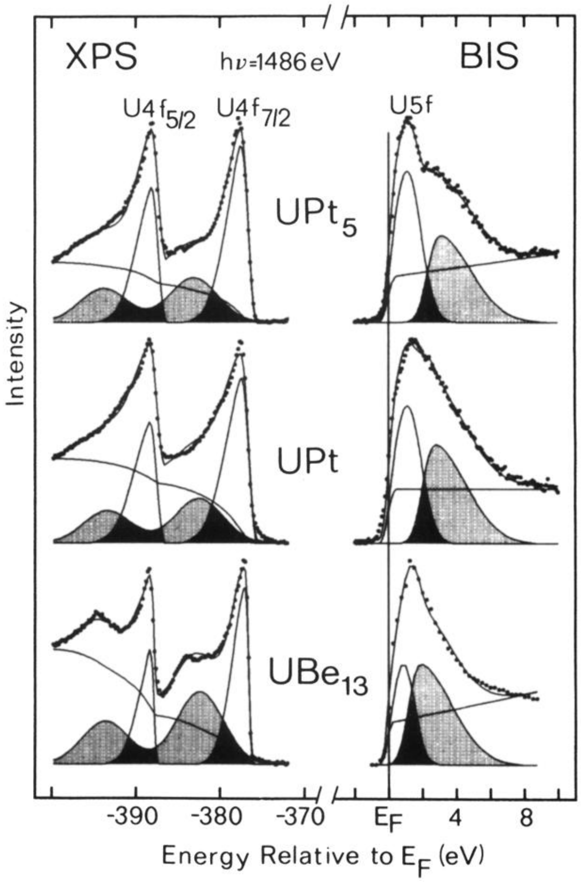

FIG. 2. U 4*f* core-level PE spectra (XPS) (on left side) and BIS spectra (on right side) of UPt_5, UPt, and UBe_{13}. The individual spectra are decomposed each into two final-state components reflecting the bandlike part of the 5*f* ground state (light-shaded subspectra) and poorly screened satellites with localized 5*f* character (dark-shaded subspectra). The data for UBe_{13} were taken from the work of Wuilloud *et al.*[8] Note the different spectrometer resolutions in case of the UPt and UPt_5 spectra on one side and the UBe_{13} spectra on the other side; also note the different energy scales on the abscissa of the XPS and BIS spectra.

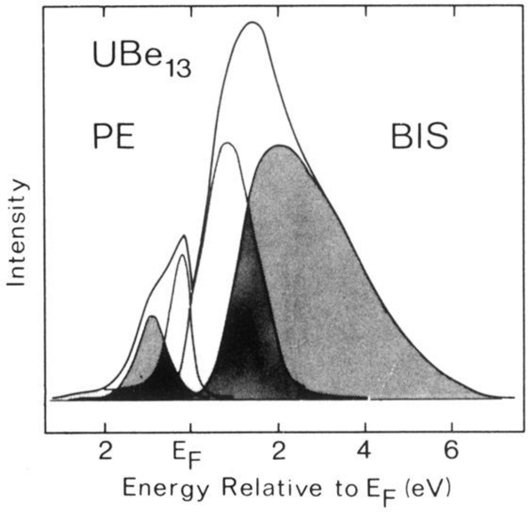

FIG. 3. Results of a consistent analysis of the U 5*f* PE and BIS spectra of UBe_{13}. In both spectra, the backgrounds have been subtracted and only the U 5*f* signals are shown for simplicity. The analysis of the U 5*f* PE spectrum is taken from Ref. 16. The light-shaded subspectra represent the *f*-screened bandlike ground state, while the dark-shaded subspectra give the poorly screened localized 5*f* satellites. Note the much higher relative intensity of the satellite in the BIS spectrum.