7.1 RE energy: Bi(111) vs Au(111)

The RE band splitting has been measured on Bi(111) as reported in the figure below.

1) Evaluate the RE energy E_R
2) Compare the Bi(111) surface ([Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^3$) with the case of Au(111) shown in the lecture (([Xe] $5d^{10}$ $6s^1$) .
   Are the splitting the same? Is there a correlation between E_R and the work function (i.e. the potential one needs to overcome to extract an electron from a given material)? Comment

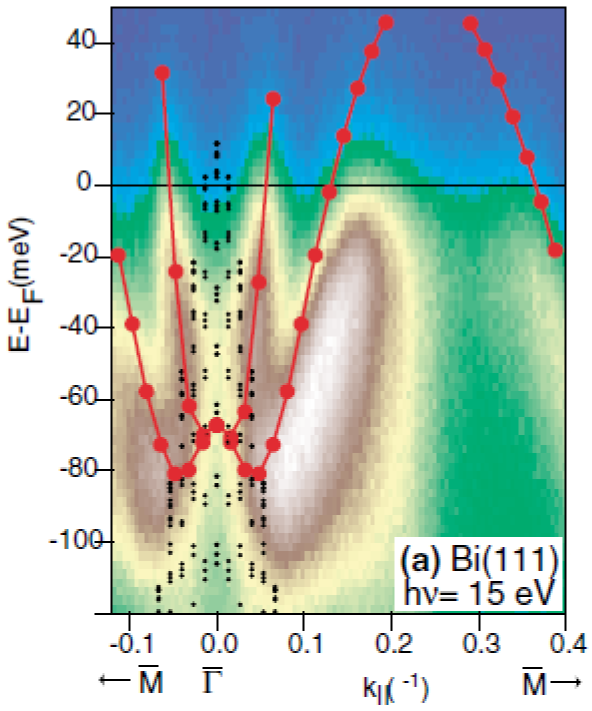

Table 1. The periodic table of elements*

$_{1}$H 13.598 0.7542																	$_{2}$He 24.58 –0.22
$_{3}$Li 5.39 2.9 0.6182	$_{4}$Be 9.32 4.98 –0.19											$_{5}$B 8.30 4.45 0.227	$_{6}$C 11.26 5.0 1.2629	$_{7}$N 14.54 –0.07	$_{8}$O 13.61 1.462	$_{9}$F 17.42 3.399	$_{10}$Ne 21.56 –0.3
$_{11}$Na 5.14 2.75 0.5479	$_{12}$Mg 7.64 3.66 –0.22											$_{13}$Al 5.98 4.28 0.442	$_{14}$Si 8.15 4.85 1.385	$_{15}$P 10.55 0.7464	$_{16}$S 10.36 2.077	$_{17}$Cl 13.01 3.615	$_{18}$Ar 15.76 –0.36
$_{19}$K 4.34 2.30 0.5015	$_{20}$Ca 6.11 2.87 0.0215	$_{21}$Sc 6.56 3.4 0.189	$_{22}$Ti 6.83 4.33 0.080	$_{23}$V 6.74 4.3 0.526	$_{24}$Cr 6.76 4.5 0.667	$_{25}$Mn 7.43 4.1 <0.005	$_{26}$Fe 7.90 4.5 0.164	$_{27}$Co 7.86 5.0 0.662	$_{28}$Ni 7.63 5.15 1.157	$_{29}$Cu 7.72 4.51 1.228	$_{30}$Zn 9.39 4.33 0.093	$_{31}$Ga 6.00 4.15 0.31	$_{32}$Ge 7.89 5.0 1.23	$_{33}$As 9.81 4.77 0.81	$_{34}$Se 9.75 5.9 2.0208	$_{35}$Br 11.84 3.364	$_{36}$Kr 14.00 <0
$_{37}$Rb 4.18 2.16 0.4859	$_{38}$Sr 5.69 2.59 0.11	$_{39}$Y 6.38 3.1 0.308	$_{40}$Zr 6.95 4.05 0.427	$_{41}$Nb 6.88 4.3 0.894	$_{42}$Mo 7.18 4.6 0.747	$_{43}$Tc 7.28 4.9 0.55	$_{44}$Ru 7.36 4.71 1.05	$_{45}$Rh 7.46 4.98 1.138	$_{46}$Pd 8.343 5.12 0.558	$_{47}$Ag 7.57 4.26 1.303	$_{48}$Cd 8.99 4.22 0.260	$_{49}$In 5.78 4.12 0.30	$_{50}$Sn 7.34 4.42 1.15	$_{51}$Sb 8.64 4.55 1.07	$_{52}$Te 9.01 4.95 1.9708	$_{53}$I 10.45 3.059	$_{54}$Xe 12.13 <0
$_{55}$Cs 3.893 2.14 0.4716	$_{56}$Ba 5.21 2.7 0.17	$_{57}$La 5.57 2.96 0.518	$_{72}$Hf 7.00 3.9 ≥0.1	$_{73}$Ta 7.89 4.25 0.323	$_{74}$W 7.98 4.55 0.816	$_{75}$Re 7.87 4.87 0.12	$_{76}$Os 8.70 4.83 1.12	$_{77}$Ir 9.0 5.27 1.566	$_{78}$Pt 8.96 5.65 2.128	$_{79}$Au 9.22 5.1 2.309	$_{80}$Hg 10.43 4.49 0.186	$_{81}$Tl 6.11 3.84 0.3	$_{82}$Pb 7.41 4.25 0.364	$_{83}$Bi 7.29 4.22 0.946	$_{84}$Po 8.43 5.0 1.9	$_{85}$At 9.64 2.8	$_{86}$Rn 10.74 <0
$_{87}$Fr 3.98 2.1	$_{88}$Ra 5.28 2.8 0.17	$_{89}$Ac 5.17 3.2															
				$_{58}$Ce 5.466 2.97 0.518	$_{59}$Pr 5.42 2.96 ≥0.1	$_{60}$Nd 5.49 3.2 ≥0.05	$_{61}$Pm 5.54 3.1	$_{62}$Sm 5.6 2.85 ≥0.05	$_{63}$Eu 5.67 2.5 ≥0.05	$_{64}$Gd 6.14 3.17 ≥0.1	$_{65}$Tb 5.85 3.15 ≥0.1	$_{66}$Dy 5.93 3.25 0.15	$_{67}$Ho 6.02 3.22 <0.005	$_{68}$Er 6.10 3.25 <0.005	$_{69}$Tm 6.18 3.1 0.035	$_{90}$Yb 6.25 3.0 0.010	
				$_{90}$Th 6.08 3.4 >0.05	$_{91}$Pa 5.89 3.7 >0.05	$_{92}$U 6.05 3.63 >0.05	$_{93}$Np 6.19 3.9	$_{94}$Pu 6.06 3.6 ≥0.05	$_{95}$Am 6.00 3.7	$_{96}$Cm 6.02 3.9	$_{97}$Bk 6.23 3.8	$_{98}$Cf 6.30 4.0	$_{99}$Es 6.42 3.3	$_{100}$Fm	$_{101}$Md	$_{102}$No	

*The numbers under the symbols of elements are the ionization energies (upper rows), work functions (middle rows) and electron affinities (lower rows), given in eV/atom.

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7.1 RE energy: Bi(111) vs Au(111) - Solution

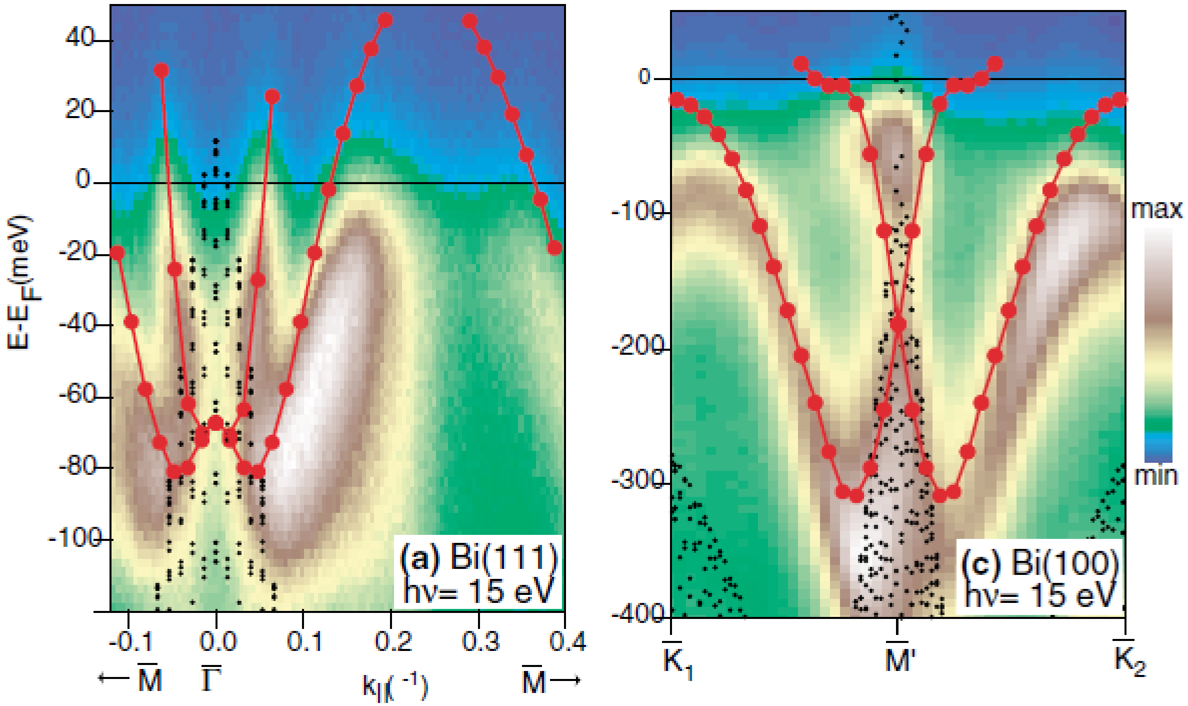
1) E_R is about 17 meV for Bi(111)

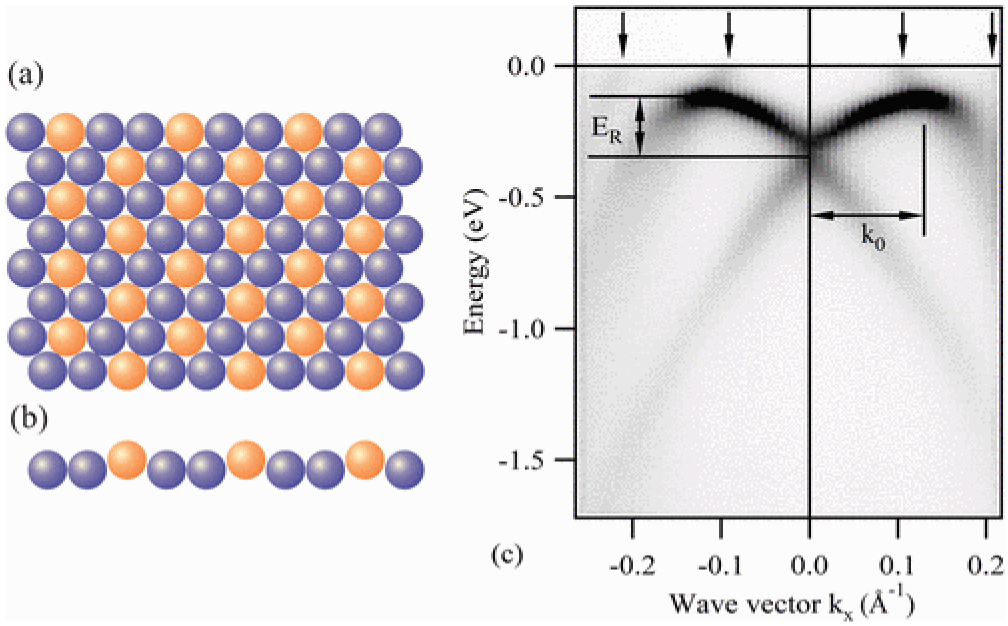
2) In the case of Au(111) E_R is about 2 meV i.e about 10 times smaller. The work function of Bi (4.22 eV) is smaller than the one of Au (5.1 eV). On the other end both Bi (Z=83) and Au (Z=79) are heavy metals with similar SOC. This big difference suggests that the Rashba effect is very sensitive to the detail of the local atomic potential

7.2 RE energy on Bi surfaces

The RE band splitting has been measured on different Bi surfaces as reported in the figures below.

1) Evaluate the RE energy E_R for the different samples
2) Compare the different Bi surfaces: are the splitting the same? comment





10.1103/PhysRevLett.93.046403; 10.1103/PhysRevLett.98.186807

7.2 RE energy on Bi surfaces - Solution

1) E_R is 17 meV for Bi(111), 130 meV for Bi(100) and 250 meV for the AgBi alloy

2) The big difference observed between the three Bi surface demonstrates that the Rashba effect is very sensitive to potential gradient in z direction but also in the x-y plane