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Supporting Information

Band Structure of EuO/Si Interface: Justification for Silicon Spintronics

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1. Si probing depth in multilayered (EuO capped by SiO_x) sample.

This section outlines our estimates of the SX-ARPES probing depth in EuO/Si samples capped by a layer of SiO_x. The estimates are largely based on the Si 2p core level spectrum measured at $h\nu$ = 1300 eV (see Figure 1 of the main text). The photoemission (PE) intensity of this level from a thick Si sample with a uniform density n_{Si} measured at normal emission can be written as

$$I_{Si}^{0} = K \cdot \sigma \cdot n_{Si} \cdot \lambda_{Si},$$

where K is an instrumental parameter, σ is the photoionization cross section, and λ_{Si} is the inelastic mean free path (IMFP) of photoelectrons in Si. When Si is covered by a thin film of EuO the intensity is attenuated by the overlayer according to the Beer-Lambert law and becomes

$$I_{Si}^{0} \cdot exp\left(-\frac{d_{EuO}}{\lambda_{EuO}}\right),$$

where d_{EuO} is the thickness of the overlaying film and λ_{EuO} is IMFP of Si 2p electrons in EuO. Similarly, addition of a capping layer of SiO_x leads to further attenuation of the PE intensity:

$$I_{Si} = I_{Si}^{0} \cdot exp\left(-\frac{d_{EuO}}{\lambda_{EuO}} - \frac{d_{SiO_x}}{\lambda_{SiO_x}}\right),$$

where d_{SiO_x} is the thickness of the capping layer and λ_{SiO_x} is IMFP of Si 2p electrons in SiO_x.

Taking into account the relatively small thickness of the SiO_x layer, the PE intensity of the Si 2p core level from the capping SiO_x can be written as

$$I_{SiO_x} = I^0_{SiO_x} \cdot \left[1 - exp\left(-\frac{d_{SiO_x}}{\lambda_{SiO_x}}\right)\right],$$

where $I^0_{SiO_x}$ is the PE intensity expected for a bulk sample of SiO_x. The ratio of the intensities is given as

$$\frac{I_{Si}}{I_{SiO_x}} = \frac{I^0_{Si}}{I^0_{SiO_x}} \cdot exp\left(-\frac{d_{EuO}}{\lambda_{EuO}} - \frac{d_{SiO_x}}{\lambda_{SiO_x}}\right) \Big/ \left[1 - exp\left(-\frac{d_{SiO_x}}{\lambda_{SiO_x}}\right)\right].$$

This ratio can be determined experimentally due to a significant chemical shift in the binding energies E_b of Si 2p photoelectrons in SiO_x with respect to bulk Si (see Figure 1 of the main text). The double peak at $E_b \approx$ -99 eV comes from the Si substrate while the broad peak at $E_b \approx$ -103 eV is assigned to SiO_x. By fitting the experimental spectra we determine the ratio of the intensities to be about 0.7.

The position of the SiO_x peak certifies that x is close to 2. Therefore, to make crude estimates we can use tabulated data for SiO_2. In particular, the ratio $I^0_{Si}/I^0_{SiO_2}$ is experimentally known to be 1.316 in standard XPS employing AlK_α photons.[S1] The value in our experiments is probably not very much different because the photon energy (1300 eV) is close to that of the AlK_α source (1468 eV). IMFP of photoelectrons in Si and SiO_2 are estimated according to the TPP-2M formula:[S2] $\lambda_{Si} \approx$ 27.5 Å and $\lambda_{SiO_2} \approx$ 33.5 Å. Taking into account the thickness values $d_{EuO} \approx$ 13 Å and $d_{SiO_x} \approx$ 17 Å, we determine that $\lambda_{EuO} \approx$ 12.4 Å.

The full set of parameters allows for analysis of the probing depth. Figure S1 illustrates how the intensity of Si 2p photoelectrons coming from different depths of the substrate is attenuated. The curve corresponding to our film is compared with that for the Si substrate. The areas under the curves determine the integrated intensity of the Si 2p substrate peak in PE spectra. The probing depth can be estimated by setting a certain detection threshold for the intensities. We choose a typical value of 2%. Figure S1 shows that the probing depth of the substrate is about 100 Å and the probing depth of the substrate covered by EuO and SiO_x is about 60 Å.

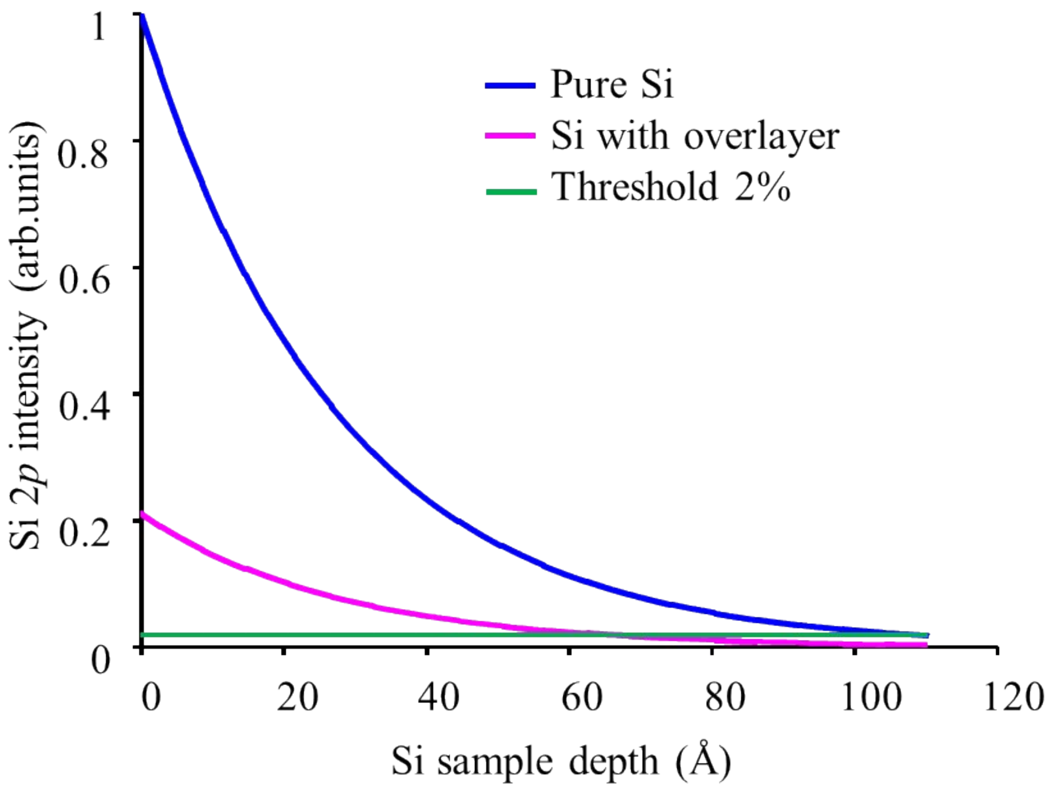

Figure S1. Attenuation of the Si 2p intensity as a function of the Si sample depth. The blue curve corresponds to Si substrate; the magenta curve corresponds to the EuO film on Si capped with SiO_x. Threshold value of 2% is shown as a green straight line.

2. Band structure of the Si substrate.

Figure 3 of the main text illustrates the response of the Si substrate at $h\nu$ = 1120 eV for three values of k_y set by tilting the sample. Figure S2 shows measurements with continuous variation of k_y. The results are presented as constant-E_b maps (CEMs) of PE intensity $I(k_x,k_y)$ for three values of E_b. Since k_z is brought to the Γ-point by setting the photon energy, these CEMs correspond to the ΓKWX plane of the Brillouin zone of bulk Si (see Figure 5b of the main text). They demonstrate well-defined contours recognizable as the textbook threedimensional dispersions of bulk Si. A separate video displays the evolution of the CEMs through the full E_b range.

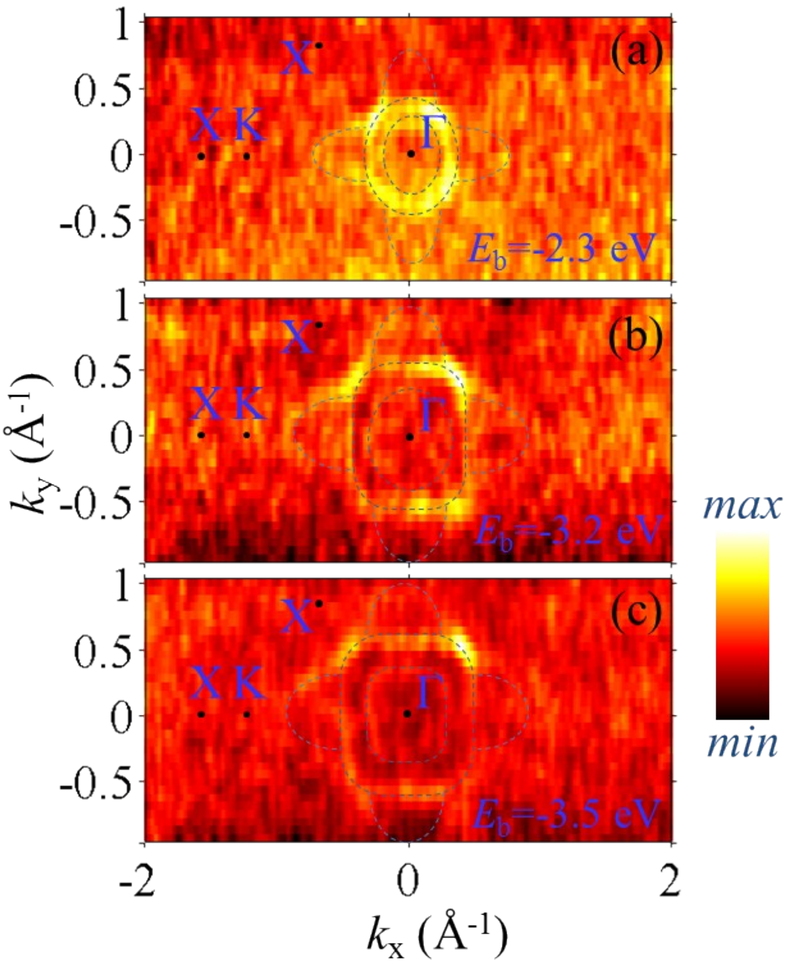

Figure S2. CEMs of PE intensity $I(k_x,k_y)$ from the Si substrate measured under continuous variation of the sample tilt for a) E_b = -2.3 eV, b) E_b = -3.2 eV, and c) E_b = -3.5 eV.

References

[S1] Seah, M. P.; Spencer, S. J. *Surf. Interface Anal.* **2002**, *33*, 640-652.

[S2] Tanuma, S.; Powell, C. J.; Penn, D. R. *Surf. Interface Anal.* **1994**, *21*, 165-176.