Ballistic electron microscopy and spectroscopy of Bi on Si(100) and Si(111)

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Motivation
- ballistic films of bismuth on silicon are ideal for the analysis of the ballistic transmission of electrons, because scattering at the surface and the interface should be minimal
- the conservation of the electronic lateral momentum has been predicted, but so far no clear experimental evidence [1][2][3]

Sample preparation
- n-type Si crystal with ohmic back contact
- HF etching
- Beating up to 1500°C
- deposition Bi: t = 150 K, 0.18 μm
- 10 nm thickness as a stack of different heights
- 200 nm thickness as a stack of different heights
- annealing 300 K, smooth [111]-oriented Bi films

Ballistic Electron Emission Microscopy (BEEM)

Four step model for BEEM [1, 2, 3]
1. Injection of hot electrons
   - tunneling through the molecules into the metal layer
2. Propagation through the metal film
   - sp., sp., and scattering
   - mean free path within the metal
3. Transmission through the Schottky barrier
   - v<sub>th</sub> exceeds Schottky barrier
   - ballistic electrons cross the barrier
   - electrons contribute to a current <i>I</i><sub>B</i> between the semiconductor and the metal film
4. Backscattering inside the semiconductor [5]
   - tunneling and backscattering of electrons into the metal film
   - reduction of the BEEM current

Conservation of the lateral momentum at the metal-semiconductor interface

Transmission for ballistic electrons higher than for Bi(100), due to the good overlap of wave functions at the metal-semiconductor interface

Mean free path of electrons for Bi films on Si(100)

- SEM images of a Schottky diode formed by two crossing stripes of bismuth on Si(100) & direct comparison of different heights
- Position of the tips is monitored by STEM
- Thickness of the diode measured ex situ by Tolskansky interferometry
- 50 spectra for each diode

Summary
- lower limit for the mean free path of electrons in thin bismuth films of 15 nm
- successful for ballistic transmission of electrons 0.1 eV barrier for Bi on Si(100)
- enhanced BEEM signal at step edges for Bi on Si(111) suggests a higher ballistic transmission for narrow parallel component of the lateral momentum of the electrons
- conservation of the lateral momentum at the Bi/Si interface

References

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