Ballistic Transport in Spin Field-Effect Transistors Built on Silicon

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The spin field-effect transistor (SpinFET) proposed by Datta and Das [1] is composed of ferromagnetic metallic source and drain contacts which sandwich a semiconductor region. Current modulation in the devices is achieved through manipulation of the orientation of the electron spin in the semiconductor channel. We consider the value of the conduction band mismatch between the contacts and the channel and the strength of the spin-orbit interaction as possible knob for controlling the characteristics of the device. Transport properties of the SpinFETs built on silicon fins are examined for a broad range of parameters including the fin orientation, the conduction band mismatch between the contacts and the channel, and the strength of the spin-orbit interaction, at different temperatures. Contrary to [2] and [3] we take into account the spin-orbit coupling in the Dresselhaus form, which is proven to be the main contribution in thin silicon films under the gate voltage applied [4]. Thereby the dependence on spin-orbit interaction of the tunneling magnetoresistance (TMR) shown in Figure 1 is important to investigate. The fin with [100] orientation exhibits a stronger dependence on β than the [110] fin of the same length. The reason is that the characteristic length of the channel at which the spin-orbit interaction starts playing a significant role is defined by $l_D = \hbar^2/(m_S\,\beta)$. Hence, for the same l_D a smaller variation of β is required to achieve the same TMR value in [100] oriented fins because of their heavier effective mass m_S. The TMR oscillates between positive and negative values [2, 3] as shown in Figure 2. As the length of the semiconductor channel increases, the period of the oscillations decreases inversely proportional to the length of the semiconductor channel. Temperature exerts a significant influence on the device characteristics. For a channel length L=1.5µm the oscillatory amplitude of the TMR dramatically decreases at T=4K, although for a channel length L=0.5µm the TMR still oscillates. Shorter channels are required to modulate the current by adjusting the conductance band mismatch at higher temperatures.

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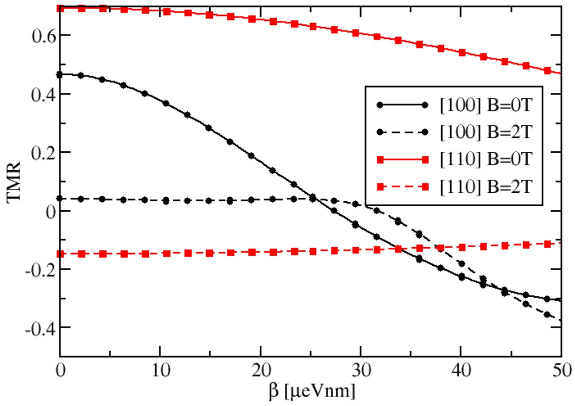

Fig. 1: *TMR dependence on the value of the Dresselhaus spin-orbit interaction for P=0.6, z=2, L=5µm.*

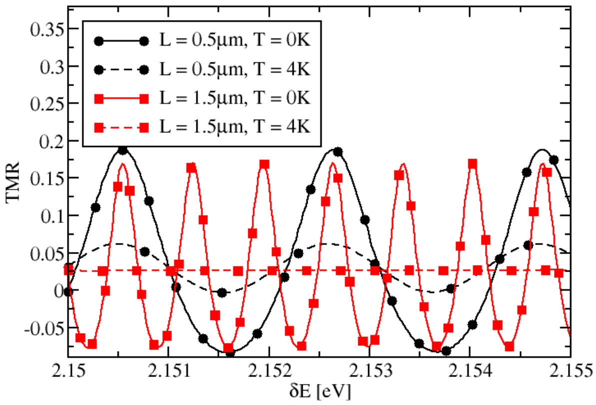

Fig. 2: *TMR dependence on the value of δE, for E_F=2.47eV, eV=0.001eV, α_R=31.7meVnm.*

References

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