Performance and limitations of Si electron nano-aspirator

Manjakavahoaka Razanoelina[1], Himma Firdaus[1], Yukinori Ono[1]
Shizuoka Univ.[1]

E-mail : razanoelina.manjakavahoaka@shizuoka.ac.jp

Electron nano aspirator is a T-shaped branch SOI MOS-transistor that enhances the output current *without additional energy* [1]. The device includes an emitter terminal, a collector terminal and a base terminal as shown Fig 1a. The emitter and the collector have their own gates, the emitter gate and the collector gate, which controls the current emission and the current flowing to the collector, respectively. A large gate, the upper gate, forms the inversion layer in the channel as well as in the emitter and the collector terminals.

In aspirator mode, electrons are injected into the channel from the emitter with a high energy ($|eV_E|$ = -1 eV) in a constant current mode (I_E = -10 nA), and with the emitter and collector terminals grounded, as shown the schematic in Fig. 1b. These energetic electrons scatter with the cold electrons in the T-branch via *e-e* scattering. During the scattering events, the injected electrons transfer forward momentum to the cold electrons and thus, create electrons – holes system [2]. Here, hole means an empty state in the conduction band. The electrons flow to the collector and therefore, leaving an accumulation of positive charges in the T-branch. The positive charge accumulation results in electrons flow from the base while the electron back-flow from the collector terminal are blocked by a hump formed by the collector gate (see the potential diagram next to measurement data in Fig 1b). As a consequence, there is a net flow form the grounded base terminal to the grounded collector terminal leading to a reverse polarity of the base current I_B and an enhancement of the collector current I_C as indicated Fig 1b. *In other words, the collector current is enhanced without requiring an additional power sources.*

If we define the current enhancement $R_I = |I_C/I_E|$, it has been shown that the maximal current enhancement at low temperature is $R_{I,\,MAX} = (|eV_E|/E_F)^{1/2}$, with the Fermi energy E_F [1]. At $|eV_E|$ = 1 eV and E_F = 32 meV, the theoretical value of $R_{I,\,MAX}$ = 5 while the experimental $R_{I,\,MAX}$ measured is around 3 and it is device to device dependent. A possible cause of this performance limitation is the surface roughness scatterings which contribute to dissipate to electron momentum in the channel. Therefore, we have investigated the dependence of the $R_{I,\,MAX}$ in function of the low bias resistance $R_{B\text{-}C}$ of the base-collector as shown Fig 1c [3]. The measurement indicates a negative correlation between the two parameters and thus offering a prospective for improvement by reducing the resistance in the base collector path.

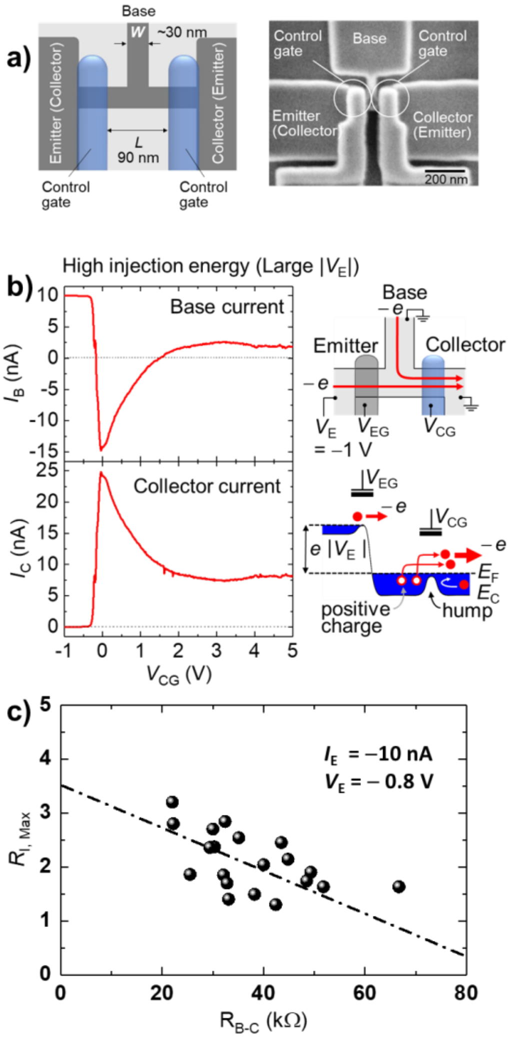

Figure 1 a) schematic top view and SEM image of the device. **b)** Base current I_B and collector current I_C in function of collector gate voltage V_{CG} for constant current injection I_E = -10 nA.. **c)** Correlation between $R_{I,MAX}$ and the resistance $R_{B\text{-}C}$ of the base-collector path. The measurements are done for 10 devices. Current injection is performed from the left terminal and right terminal for each device.

[1]. H. Firdaus *et al.*, *Nat. commun*. **9**, 4813 (2018).
[2]. I. I. Kaya *et al.*, *Phys. Rev. Lett.* 98, 186801 (2007).
[3]. M. Razanoelina *et al.*, SNW2019

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