Ni ナノ接合の通電断線における4領域の観察

Observation of four regions in the electromigration process of Ni nanojunctions

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To add novel functions to molecular spintronic devices, the use of ferromagnetic electrodes has been attracting considerable attention to investigate quantum states at the single molecule level. However, fabrication of ferromagnetic (FM) nanogap electrodes by electrical break junction (EBJ) method [1] and formation of single molecule transistors with FM electrodes [2] have been difficult mainly because of the high melting temperatures of FM metal species. Therefore, it is necessary to clarify the elementary processes of EBJ process for FM nanojunctions.

In this work, we have applied the feedback controlled EBJ process [1] to Ni nanojunctions in vacuum at ~4.2 K. Ni nanojunctions with an asymmetric pattern shape were fabricated by using the shadow evaporation technique, as shown in the SEM image of Fig. 1(a). In the EM process, we applied a voltage and monitored the conductance as a function of time. We define the critical junction voltage, V_C, to be the voltage at which the junction conductance is reduced by more than 80%. We plot V_C as a function of the junction resistance R_J, as shown in Fig. 1(a). R_J is normalized in in the unit of the quantum resistance $R_0 \equiv h/2e^2$. The V_C-R_J curve reveals that we have 4 different regions in the EM process. Fig.1(b) show the corresponding four *G*-*V* relationships as a function of time. Among these four phases, regions 3 and 4 were identified to be the diffusive heating region and the ballistic transport regions [1], respectively. We would like to mention that the necessary Joule heating power of Ni junctions was about 0.18 mW, while it is 0.8 mW for gold nanojunctions at 4.2 K, reflecting the difference in the melting temperature of the two metal species. Furthermore, in region 4, successive step-like conductance drops are observed, which indicates the transport in this region is ballistic. These two regions are also observed in the EBJ process of gold nanojunctions [1]. Interestingly, we have observed two more distinctive regions; when the junction resistance $R_J < 1.2\times10^{-3}R_0$ (region1) 1, a linear relationship between R_J and V_C has been observed. The origin of this behavior is not clear yet. Furthermore, when $1.2\times10^{-3}R_0 < R_J < 1.5\times10^{-2}R_0$ (region 2), the R_J-V_J trace indicates that atoms are removed when $V_J = 0.19$ V. This value (0.19 eV) is very close to the surface diffusion potential of Ni atoms on the (110) surface. At the conference, we will discuss more about the mechanism.

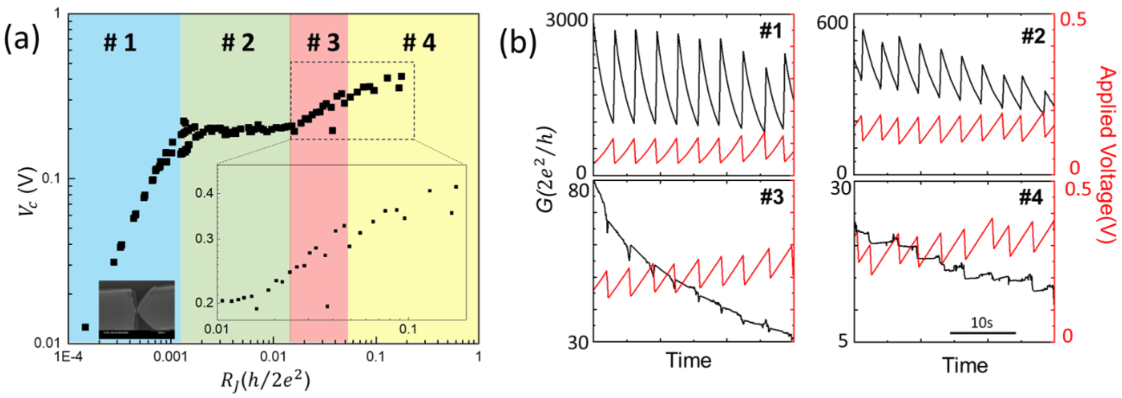

Fig.1(a)SEM of Ni junction and V_C and R_J relationship in the log coordinate system (b) Corresponding G/V-Time curves of different regions

References [1] A. Umeno and K. Hirakawa, *Appl. Phys. Lett.* **94**, 162103 (2009). [2] K. Yoshida *et al.*, *Nano Letters*, **13**, pp. 481-485, (2013).