Abstract #2235, 224th ECS Meeting, © 2013 The Electrochemical Society

Study on Charge Storage and Optical Response of Hybrid Nanodots Floating Gate MOS Devices for Their Optoelectronic Application

Seiichi Miyazaki
Graduate School of Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan
E-mail: miyazaki@nuee.nagoya-u.ac.jp

We have proposed and fabricated hybrid stacked structures consisting of metallic nanodots (NDs), Si-QDs and ultrathin interlayer SiO_2 which lead us to satisfy both multiple valued capability and charge storage capacity for a sufficient memory window and to open up novel functionality [1, 2]. In this paper, we have reviewed our recent achievement on the characterization of the hybrid nanodots floating gate (FG), including optical response of electrons in FG to near-infrared light irradiation which is caused by the transfer of photo-excited electrons from metallic NDs to Si-QDs.

Hybrid stacked structures consisting of NiSi-NDs, ultrathin interlayer SiO_2 and Si-QDs were fabricated through the following process sequence. Hemispherical Si-QDs were firstly formed on an ultrathin thermally-grown SiO_2 by controlling the early stages of LPCVD of pure SiH_4 at 580°C. The areal dot density and the average dot size evaluated by AFM measurements were typically ~5nm and ~$3.5x10^{11}cm^{-2}$, respectively. And then, the Si-QDs surface was slightly oxidized in O_2 at 850°C, and followed by SiO_2 deposition from inductively-coupled remote plasma (ICRP) of SiH_4 and excited O_2/Ar at 350°C to obtain the designed thickness. Subsequently, the 2nd formation of Si-QDs was carried out under the same conditions as the first formation of Si-QDs, and the surface was covered uniformly with a ~1.8nm-thick Ni layer by electron beam evaporation and successively exposed to remote H_2 plasma without external heating to enhance surface migration of Ni atoms and Ni-silicidation, which results in uniform formation of NiSi-NDs. Again the formation of Si-QDs was preformed after ICRP-CVD of ultrathin SiO_2 on NiSi-NDs. Lastly, the top control oxide with a thickness of ~20nm, Al gates with a diameter of 1 mm and Al back contact with a window for light irradiation were sequentially fabricated to complete hybrid FG MOS structures.

High-frequency capacitance-voltage (C-V) characteristics of the MOS capacitor with the hybrid FG show positive and negative flat-band voltage shifts depending on the porality and the maximu magnitude of applied gate bias and cofirm stable charge strorage in a deep potential well in each of NiSi-NDs as predicted from observed work function value of ~4.53±0.05eV [3]. In the application of plused gate bias, we also confirmed a stepwise increase in flat-band voltage shift with increasing gate pluse width, being attibutable to election injection through the discrete energy states in Si-QDs to NiSi-NDs. Since electrons in NiSi-NDs can be excited by irradiation of infrared light being transparent to the Si substrate and Si-QDs, electron trasnfer from NiSi-NDs to Si-QDs selectively is expected to be caused by such a infrared light irradiation, which can be observed as a flat-band voltage shift due to the change in the centrode of conduction electrons in the hybride FG. With a decrease in the internal SiO_2 thickness down to 1.4nm, a distinct capacitance changes due to the flat-band voltage shift induced by 1310nm-light irradiation was detectable even at zero gate bias as expected. And in the mesurements under chopped 1310nm-light, we confirm no change in the dark capactance, namely no change in the total amonut of electrons in hybrid FG with such sub-gap light irradiation. We have also evaluated such a light-induced electron transfer in the hybrid FG stack by measuring transient current induced by chopped subgap-light as a function of chopped frequency, in which the sample was connected with a 1 MΩ resistance in series and the voltage drop across the resistance was measured with a lock-in amplifier (see the inset of Fig. 1). Obviously, response signals were reduced with an increase in chopped frequency as shown in Fig.1. The result is interpreted in terms mainly that electron tunneling rate through the internal oxide limits the transfer of photoexcited electrons from NiSi-NDs to Si-QDs. In fact, with increasing gate bias, response signals are increased and the response speed is improved markedly.

Acknowledgments

The author wishes to thank Drs. M. Ikeda, H. Murakami and Prof. S. Higashi of Hiroshima Univ. and Dr. K. Makihara of Nagoya Univ. for their support and contribution. This work was supported in part by Grants-in Aid for Scientific Research (A) No. 24246054 from the Ministry of Education, Culture, Sports, Science and Technology, Japan. In addition, the author deeply appreciates that MOSFETs with hybrid NDs FG were fabricated successfully by utilizing the clean room facilities of Research Institute for Nanodevice and Bio Systems (RNBS), Hiroshima Univ.

References

[1] S. Miyazaki, et al., Thin Solid Films, 518 (2010) 530.
[2] N. Morisawa, et al., Jpn. J. Appl. Phys. 49 (2010) 04DJ04.
[3] S. Miyazaki et al., Mat. Sci. Forum 638-642 (2010) 1725.

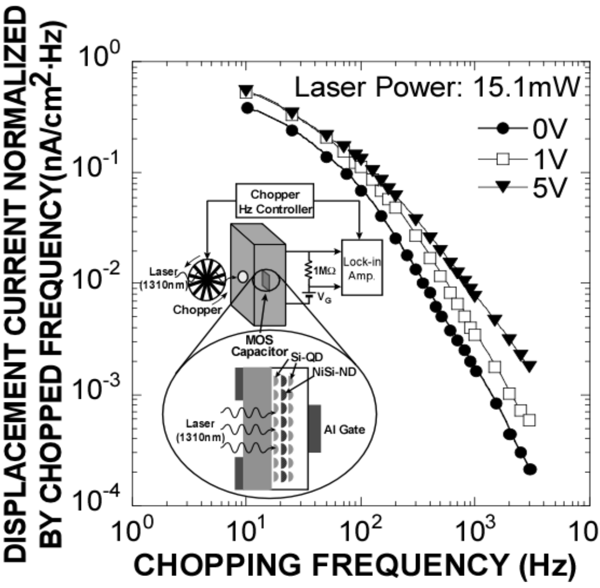

Fig. 1 Light-induced displacement current, which was normalized by chopping frequency of subgap light, as functions of chopping frequency at three different applied gate voltages. A schematic view of an experimental setup to evaluate optical response to chopped 1310nm subgap-light is shown in the inset.