Helium Ion Microscope (HIM) Characterization for Nano-Device Structures - SE Imaging and Ion Beam Luminescence Detection -

Shinichi Ogawa, Tomohiko Iijima, Shogo Awata*, Shigeru Kakinuma*, Shintaro Komatani*, and Toshihiko Kanayama
Nanodevice Innovation Research Center, National Institute of Advanced Industrial Science and Technology (AIST)
West 7A, 16-1 Onogawa, Tsukuba, Ibaraki 305-8569 Japan.
*Horiba Scientific/Semiconductor Instruments & Systems Division, HORIBA, Ltd.
2 Kisshouin - Miyanohigashi, Minami-ku, Kyoto 601-8510, Japan

Abstract

This paper discusses the several imaging modes that may make HIM [1] a tool of particular value to soft materials such as low-k dielectrics with less transformation and copper interconnect buried in dielectrics, and shows possibility of detection of luminescence induced by the focused helium ion beam using the HIM for the first time.

The imaging of fine line features patterned in low-k materials is important for ULSI Cu/low-k interconnect validation of the dry etch, wet clean, e.g., in back end process steps, while conventional secondary electron microscope (SEM) imaging of low-k materials often results in changes to the low-k material line width, edge roughness, and shape by damage during the SEM electron beam irradiation. The HIM could provide low-k dielectric secondary electron (SE) image with nm order resolution, deeper focus depth, less transformation because of lower thermal energy transfer into a unit volume of the low-k material (three order magnitude) than the SEM under an appropriate operation condition [2), 3)]. The helium ion / sample interaction was also investigated. A new imaging mode, through the inter-level dielectric, of the underlying copper, was explored as well. Cu interconnect was seen through a 130 nm thick low-k dielectrics (Fig.1). It might be because the incident helium ions generated secondary electrons at the buried Cu surface and the secondary electrons of 1-2 eV energy passed through the dielectric of a few eV band gap without any energy transfer, and then the image was obtained. Helium ion channeling at the Cu surface area varied the secondary electron quantity, and it resulted in a crystal orientation contrast information of the buried Cu interconnect surface.

Luminescence induced by the focused helium ion beam was studied using the HIM for the first time for characterization of the dielectrics properties. Helium ion beam of a few pA current was irradiated onto a SiO2 film surface, and peaks in a spectrum were observed at around 281 nm, 447 nm, and 672 nm (Fig. 2) ; these positions were different from those by a conventional cathode luminescence using a SEM [4)]. In a case of the SiO2 film, intensity of the peaks increased with a number of irradiations, on the other hand, in a case of the low-k film, intensity of a broad peak at 300–480 nm decreased. This presumably is because the materials were modified or damaged during the helium ion beam irradiation. The phenomena have not been well understood so far, and further study will be presented.

We would like to acknowledge W. Thompson, L. Stern and J. Nottte of Carl Zeiss Inc. for their assistance in the Cu / low-k works, and M. Matsuura, and K. Goto of Renesas Electronics Corp. for supplying dielectric film samples.

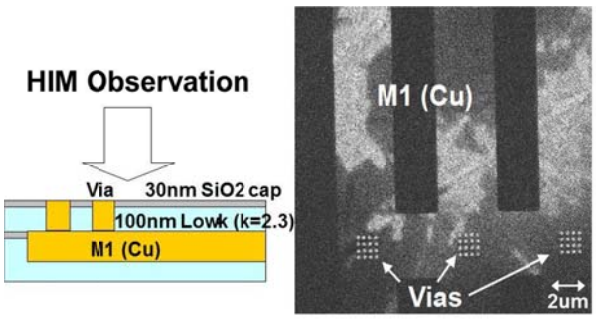

Fig.1 Side view of a Cu/low-k structure (Left) and M1 (Cu) seen through a 130 nm thick low-k dielectric material (Right)

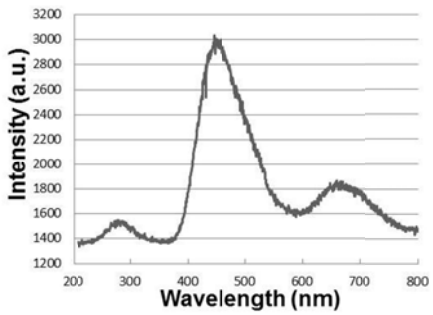

Fig.2 Spectrum of the HIM helium ion beam induced luminescence from SiO2 film

References

1) L. Scipioni, W. Thompson, S. Sijbrandij, and S. Ogawa: Proc. Int Reliability Physics Symp., 2009, p. 317, 2) W. Thompson, S. Ogawa, L.Stern, L. Scipioni, and J. Notte,, Proc. of International Interconnect Technology Conference p.69 (2009), 3) S. Ogawa, W. Thompson, L. Stern, L. Scipioi, J. Notte, L. Farkas, and L. Barriss, Jpn. J. Appl. Phys., 49 (2010) 04DB12, 4) M. Kodera, S. Uekusa, S. Kakinuma, Y. Saijo, A. Fukunaga, M. Tsujimura, and G. Pezzotti, Proc. of International Interconnect Technology Conference p.212 (2005)

Key words : Helium ion microscope, Cu/low-k interconnect, Luminescence