Extended Abstract of PSA-19

O-03

Round-Robin Test of Medium-Energy Ion Scattering for Quantitative Depth Profiling of Ultrathin $HfO_2/SiO_2/Si$ Films

Won Ja Min[1], Gabriel M. Marmitt[2], RRT Participants, Pedro L. Grande[2], and DaeWon Moon[3]

[1] *MEIS dev. Team. K-MAC, Techno 8-ro 33, Yuseong, Daejeon 34028, Korea*

[2]*Ion Implantation Laboratory, Institute of Physics, Federal University of Rio Grande do Sul, Av. Bento Gonçalves 9500, CP 15051, CEP 91501-970, Porto Alegre, RS, Brazil*

[3]*Department of New Biology, DGIST, Techno-JungAngDaeRo 333, Dalseong, Daegu 42988, Korea*

*corresponding author's e-mail: dwmoon@dgist.ac.kr & grande@if.ufrgs.br

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Medium energy ion scattering (MEIS) has been used for quantitative depth profiling of ultrathin films with single atomic layer resolution. To assure the consistency of the MEIS analysis, an international round-robin test with nominally 1, 3, 5, and 7 nm thick HfO_2 films was conducted among 12 institutions. The standard deviations were 5.3% for the composition, 15.3% for the thickness, and 13.3% for the Hf content by using stopping and range of ions in matter (SRIM) 95, and they were improved to 7.3%, 4.5%, and 7.0% by using refitted electronic stopping powers based on the experimental data. This study suggests that correct electronic stopping powers are critical for quantitative MEIS analysis.

1. Medium Energy Ion Scattering

Medium energy ion scattering (MEIS) is a surface analysis technique that uses medium-energy (100–500 keV) ions. When incident ions hit the sample, the ions are scattered by the target nuclei of the sample. The scattered energy of the ions is reduced by the kinematic factor, which is determined by the mass ratio of the incident ion and the target nucleus, and the scattering angle. Additional energy loss occurs during ion beam path by the stopping power before and after the collision. The scattering yield of each element is determined as a function of concentration and the scattering cross section. As a result, the elemental concentration depth distributions in thin films is determined by measuring the scattering yield as a function of scattered ion energies.[1]-[2]

2. Round-Robin Test (RRT)

Nominally 1, 3, 5, and 7 nm thick HfO_2 films were deposited by atomic layer deposition on a 12 nm thermal SiO_2 layer. The thermal SiO_2 layer is used as an internal reference in analysis. The measurements were performed at each participating laboratory under their own conditions and the collected data were analyzed at K-MAC by using powermeis program[3]. Participants are presented at Table 1.

Table 1. List of participants in the round-robin test

Participants	Organization
L. Goncharova	Western University, Canada
K. Kimura	Kyoto University, Japan
T. Gustafsson	Rutgers University, USA
M. Copel	IBM Watson, USA
J. Ko	SK hynix, Korea
H.-I. Lee	SAIT, Korea
S. Lee	Samsung Electronics, Korea
K. Chae	KIST, Korea
J. van den Berg	University of Huddersfield, UK
K. Jung	DGIST, Korea
K. Park	KMAC, Korea
G. Marmitt	UFRGS, Brazil

For the data analysis, the Moliere potential[4] for scattering cross section, and the Chu [5] for straggling were used. For the electronic stopping power, the MEIS results obtained using the SRIM 95[6] values and the ones corrected with the IAEA data[7] were compared. For analyzing the MEIS data from the magnetic sector and electrostatic analyzers, the neutralization corrections of Marion and Young[8] for 100 keV H^+ and He^+ ions and of Armstrong[9] for 400–500 keV He^+

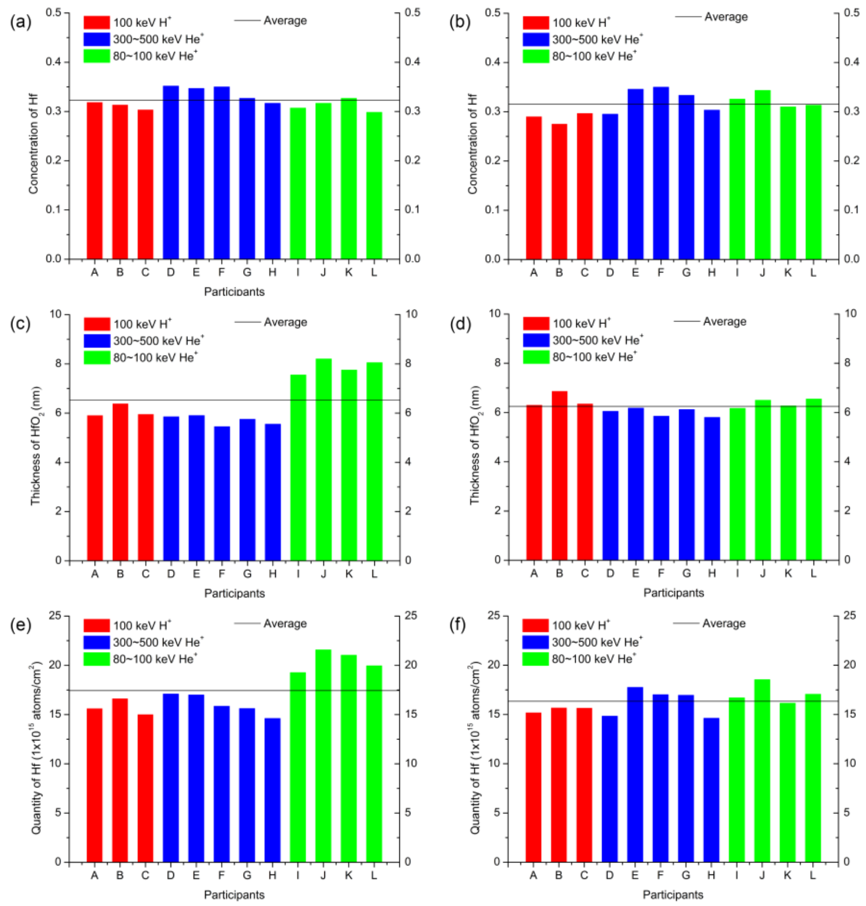

Fig. 1. Comparison of results obtained for the 7 nm HfO_2 sample: Hf concentration with (a) SRIM 95 and (b) new fitted electronic stopping power; HfO_2 layer thickness with (c) SRIM 95 and (d) new fitted electronic stopping power; and Hf surface areal density with (e) SRIM 95 and (f) new fitted electronic stopping power.

ions were used. As a result, the concentration of Hf, thickness of the HfO_2 layer, the quantity of Hf were obtained, and results of the 7 nm HfO_2 sample are presented at Fig.1 among all data. The average values were 32.3 % for Hf concentration, 6.52 nm for HfO_2 layer thickness, and 1.74×10^{16} atoms/cm^2 for Hf areal density by using SRIM95 stopping power. The standard deviations were 5.3% for the composition, 15.3% for the thickness, and 13.3% for the Hf areal density. When they are analyzed by using refitted electronic stopping powers based on the experimental data[7], the average values were 31.5 % in Hf concentration, 6.25 nm in HfO_2 layer thickness, and 1.63×10^{16} atoms/cm^2 in Hf areal density, and the standard deviations were improved to 7.3%, 4.5%, and 7.0% respectively.

3. Conclusion

The RRT was conducted to investigate the consistency in the concentration of Hf, the HfO_2 layer thickness, and the surface areal density of Hf determined by MEIS analysis for nominally 1, 3, 5, and 7 nm thick HfO_2 films. As a result, the corrected electronic stopping power values provided more consistent results with relative standard deviations of 2–8.2%, compared to the SRIM 95 values, with relative standard deviations of 5.3–15%, for the Hf concentration, the HfO_2 layer thickness, and surface areal density.

4. References

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