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# Monitoring of low-temperature plasma processes by in-situ impedance spectroscopy

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Impedance spectroscopy is a method for investigating the electrical properties of a system by applying an AC voltage and measuring the amplitude and phase of the current.[1] This method has been developed in electrochemistry and applied to the analysis of batteries,[1] resistance-switching materials,[2] and organic semiconductor devices.[3] In this study, we developed a method for monitoring low-temperature plasma processes based on the impedance spectroscopy.[4] Considering the features of low-temperature plasma and process equipment, we developed a system to achieve in-situ measurement of the material impedance under plasma exposure. Figure 1 illustrates a schematic of in-situ impedance spectroscopy and equivalent circuit model for plasma–material interaction, taking into account the sheath and surface-modified layer.

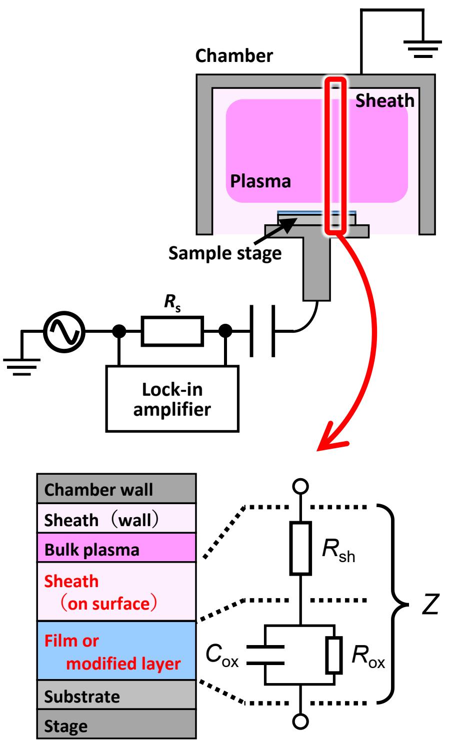


Figure 1: Schematic of experimental setup of in-situ impedance spectroscopy and equivalent circuit for the analysis of measured impedance used in this study.[4]

The developed system of in-situ impedance spectroscopy successfully monitored the degradation of $SiO_2$/Si structures exposed to low-temperature Ar plasma. In addition to the decrease in $SiO_2$ film thickness, we observed degradation in the dielectric properties of the $SiO_2$ film due to ion irradiation, as shown in Fig. 2.[5] Additionally, the surface modification process (metal oxidation) was monitored using in-situ impedance spectroscopy in an $Ar/O_2$ plasma. From measured impedance spectra, we found that the plasma potential changed as the surface-modified layer formed during the process, due to changes in charge transport between the plasma and the metal surface.[6]

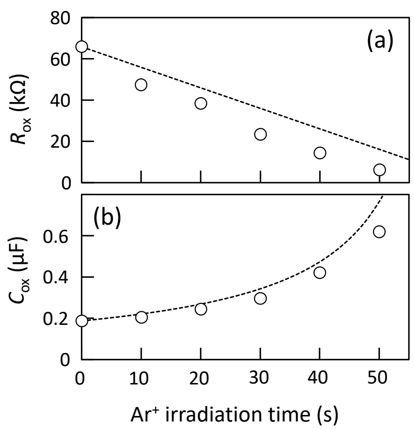


Figure 2: $R_{ox}$ and $C_{ox}$ values of $SiO_2$ film as a function of high-energy $Ar^+$ irradiation time. Dotted lines represent estimated Rox and Cox assuming constant resistivity and dielectric constant at the measured values at 0 s.[5]

Our studies demonstrate that the in-situ impedance spectroscopy can simultaneously capture the plasma and surface properties during plasma–material interactions. The simplicity of the measurement system makes it suitable for integration into advanced plasma-processing tools. Ongoing challenges for measurement include improving the measurement speed and developing detailed electrical models for plasma-exposed materials.

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