Frequency – Dependent on Electrical Characteristics of $Er_2O_3/SiO_2/n\text{-}Si/Al$ MOS Capacitor deposited by E-beam

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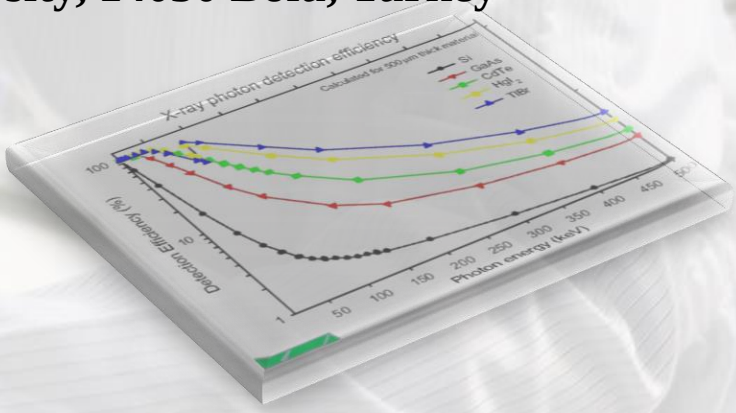

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CONTENT OUTLINE

- **INTRODUCTION**
- **EXPERIMENTAL**
- **RESULTS AND DISCUSSIONS**
- **CONCLUSION**

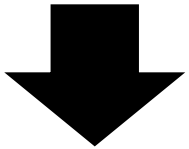
INTRODUCTION

The Metal –oxide-semiconductor MOS capacitor can be thought of as parallel plate capacitor. The MOS capacitor has three parts as a top metal contact / dielectric material/ semiconductor. The MOS capacitor is used to energy storage device applications due to the dielectric property. In studies conducted so far the oxide layers of various types, such as HfO_2, ZrO_2, Al_2O_3, La_2O_3, Er_2O_3, TiO_2, Gd_2O_3 have been used between the metal and the semiconductor. In real MOS capacitors, the localized interface states exist at the semiconductor-insulator interface and the device behaviour is different from an ideal cases due to the presence of these localized states. Moreover, the parameters such as interface states (Nss) and series resistance(Rs) affects the electrical characteristics of MOS [1-9]. Er_2O_3 is a promising high-k layer and has pulses over SiO_2 because of a high dielectric constant(10-14) a wider bandgap (5.4eV), largely conduction band offset(3.5eV), and lower gate leakage current. The purpose of this work is to investigate the frequency dependent on the electrical characteristics of $Al/Er_2O_3/SiO_2/n\text{-}Si/Al$ MOS capaictor deposited by e-beam evaporation technique.

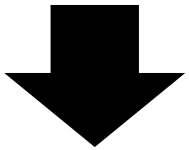
• EXPERIMENTAL

Before deposition, the wafer was cleaned by following the standard RCA cleaning steps and the oxide layer was then grown on Si wafer in diffusion furnance by dry oxidation method at 1000℃. The wafer was then inserted into E-beam evaporation set up for Er_2O_3 deposition and the deposition pressure was below 5.0×10 -4 Torr and the growth rate was about 1.5 Å/s. The thickness of SiO_2 and Er_2O_3 layers were measured by using Angstrom Sun Spectroscopic reflectometer and found to be 20 nm and 130 nm, respectively. The Er_2O_3 /SiO_2 films were annealed at 550℃ for 30 min, under N_2 ambient with the flow rate of 1000 sccm. The front and back contacts were produced with Aluminum (Al) by RF magnetron sputtering technique. On the other hand, the front Al electrodes were produced with aid of the shadow mask and the mask consists of 1.5 mm circular dots. As schematically shown in Fig. 1, the Al/Er_2O_3 /SiO_2 /n-Si/Al MOS capacitors were fabricated. The electrical measurements; C-V and G/ω-V measurements were performed by using a Keithley 4200-SCS Parameter Analyzer for the voltage raised from -10 V to 10 V in the frequency range of 50 kHz to 1 MHz. All the experiments were performed at room temperature.

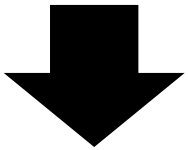
RCA Cleaning Process of n-Si wafer



SiO_2 growth on n-Si wafer by dry oxidation method



Er_2O_3 thin film deposition on SiO_2/n-Si by e-beam evaporation technique



Metallization Process

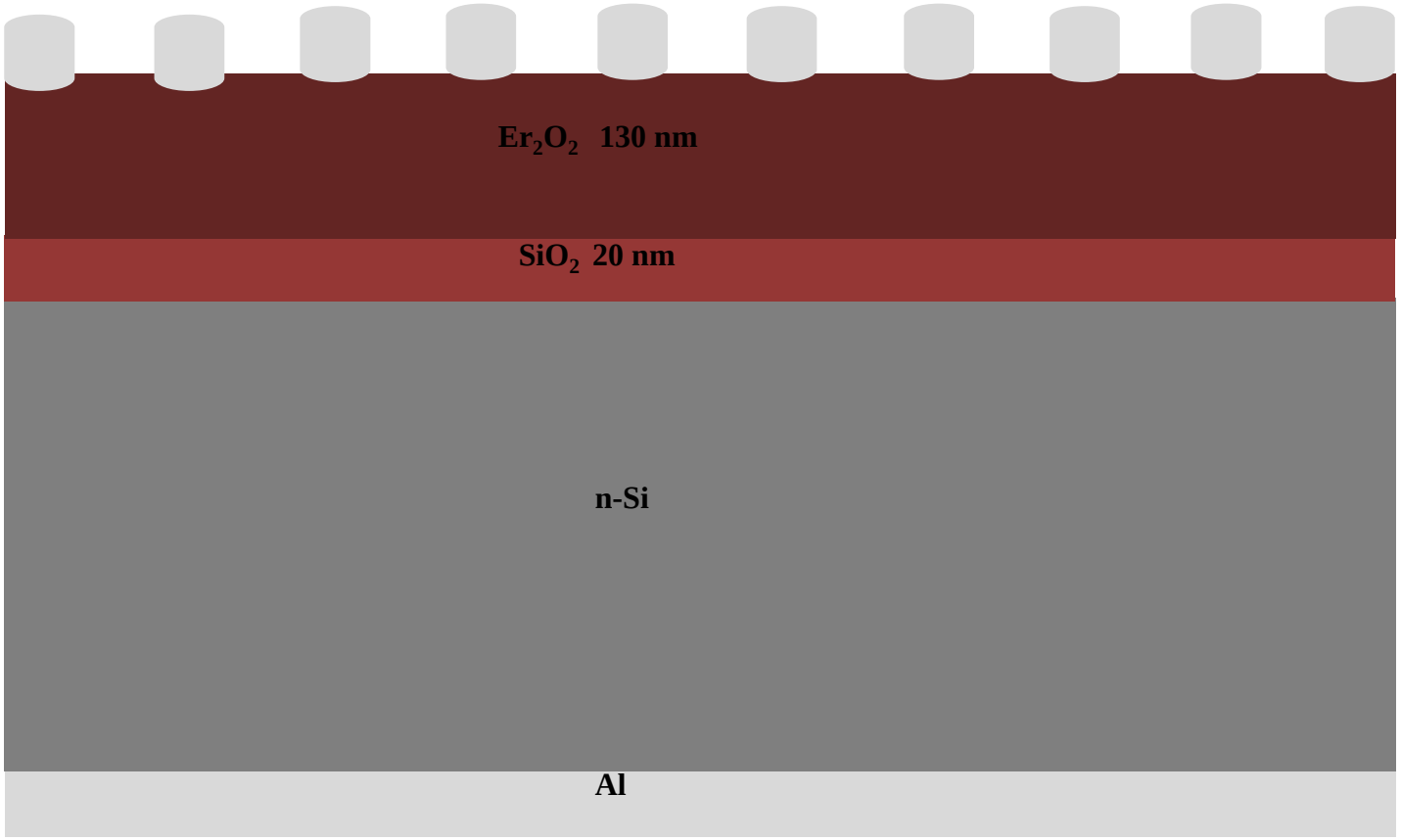


Figure 1. Structure of Al/(Er_2O_3/SiO_2/n-Si/Al) MOS Capacitors

RESULTS AND DISCUSSIONS

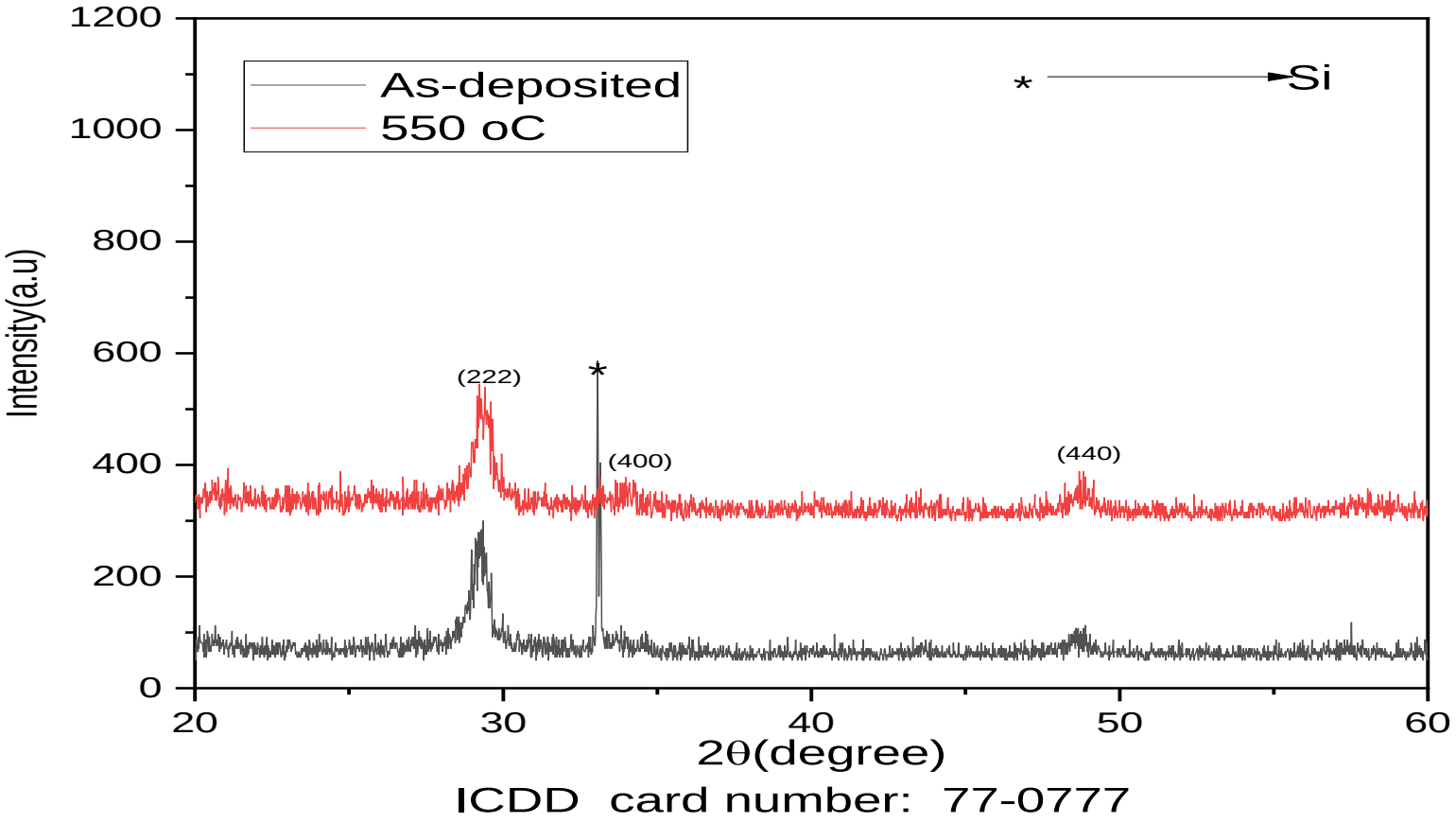


Figure 2. XRD spectra of Er_2O_3/SiO_2 thin film grown on n-Si(100) substrate

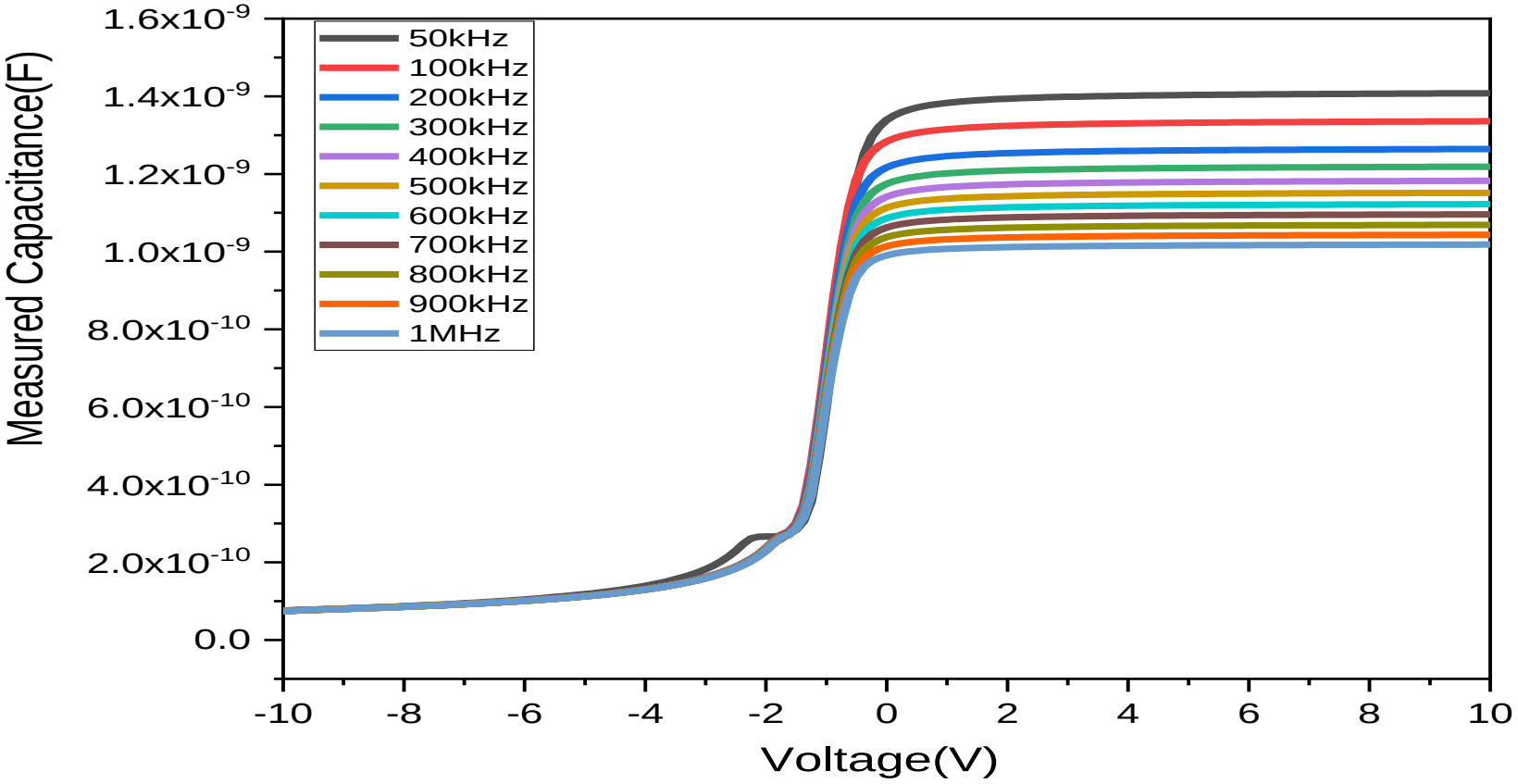


Figure 3. Measured capacitance (C_m) of Al/Er_2O_3/SiO_2/n-Si/Al MOS Capacitor for various frequency ranges from 50kHz to 1MHz

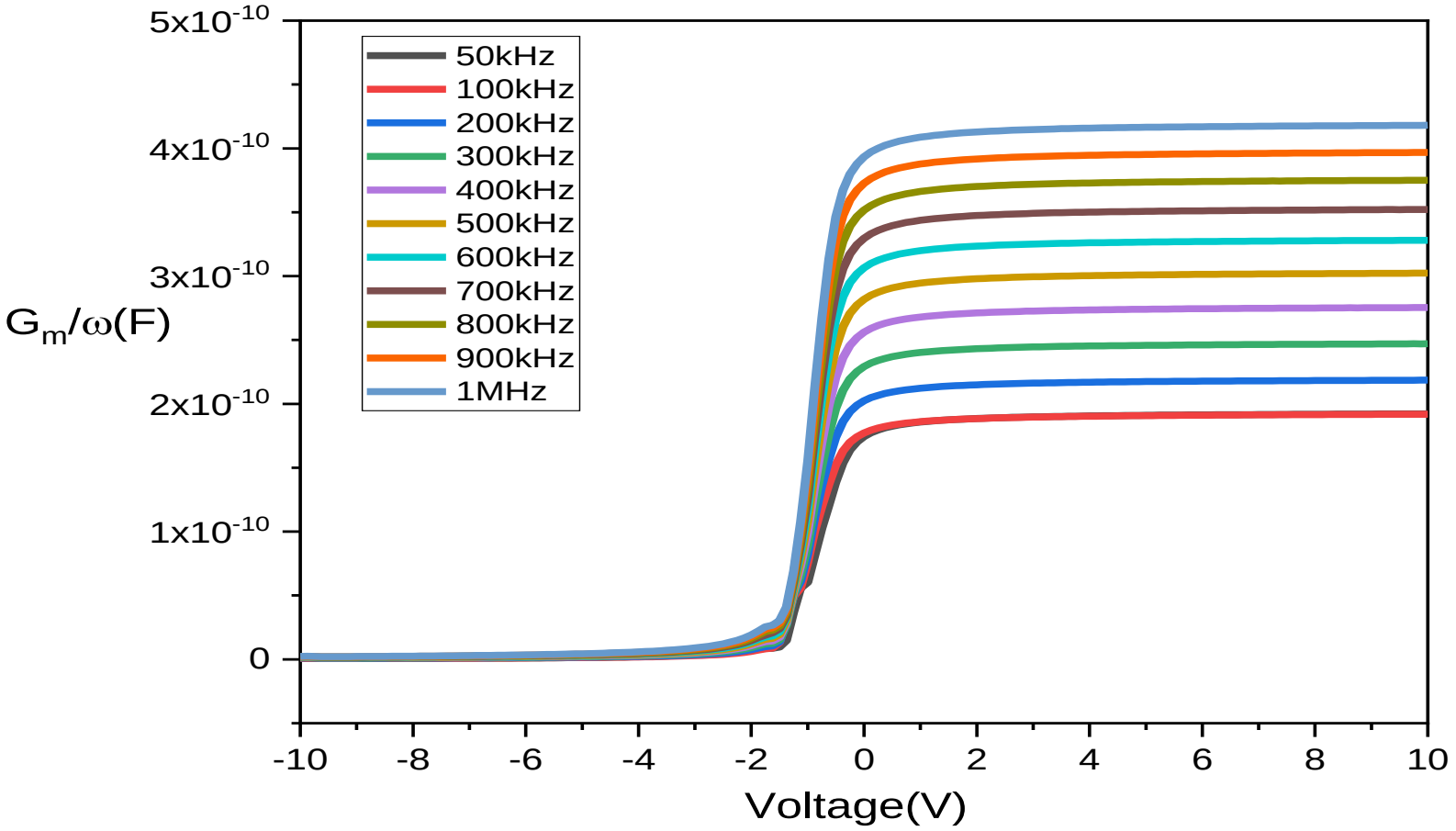


Figure 4. Measured Conductance(G_m) of Al/(Er_2O_3/SiO_2/n-Si/Al)MOS Capacitor for various frequency ranges from 50kHz to 1MHz

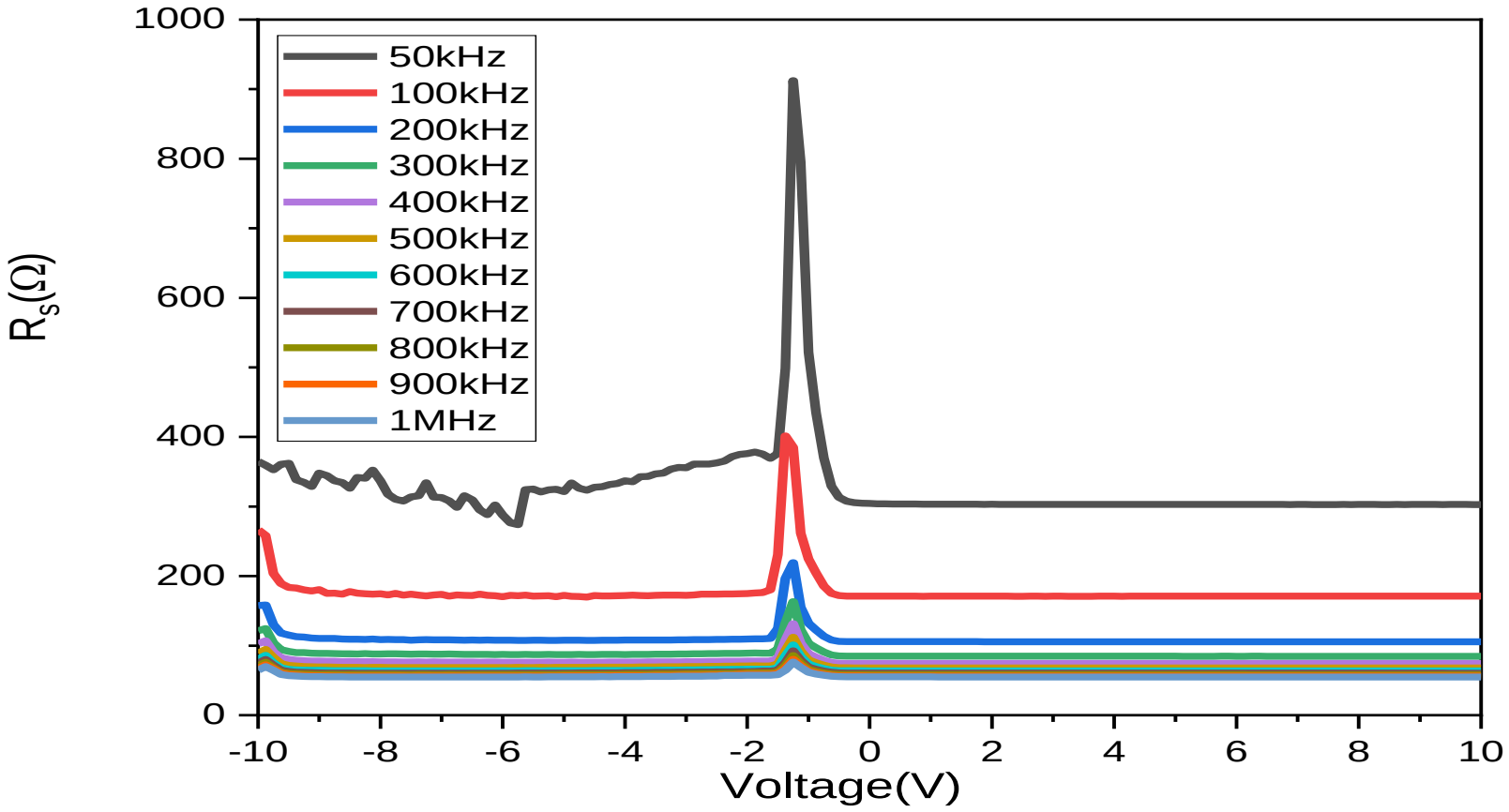


Figure .5 Series resistance curves of Al/(Er_2O_3/SiO_2/n-Si/)Al MOS Capacitor for various frequency ranges from 50kHz to 1MHz

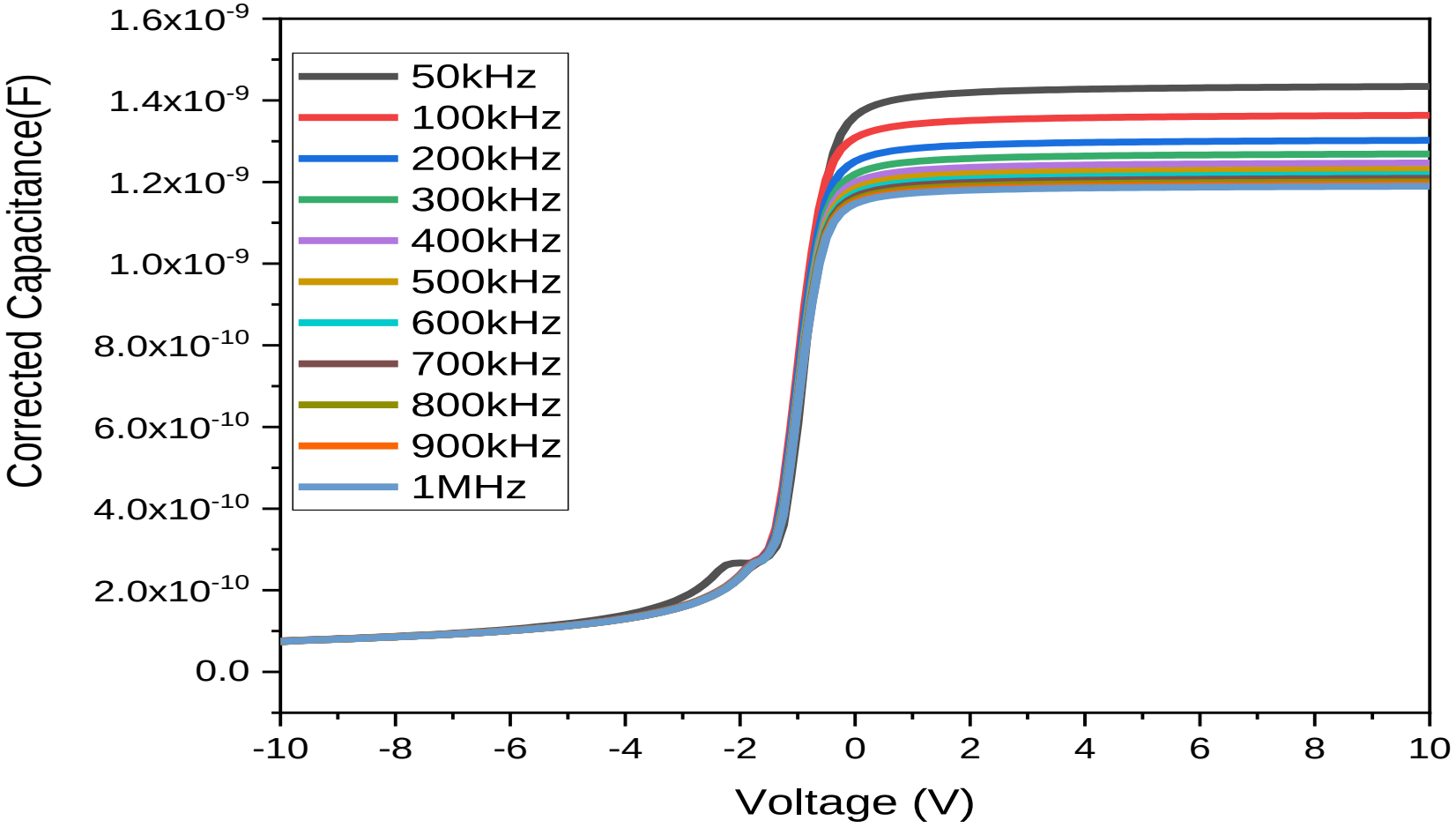


Figure.6 Corrected Capacitance(C_c) characteristics of Al/(Er_2O_3/SiO_2/n-Si/)Al MOS capacitor for various frequency ranges from 50kHz to 1MHz

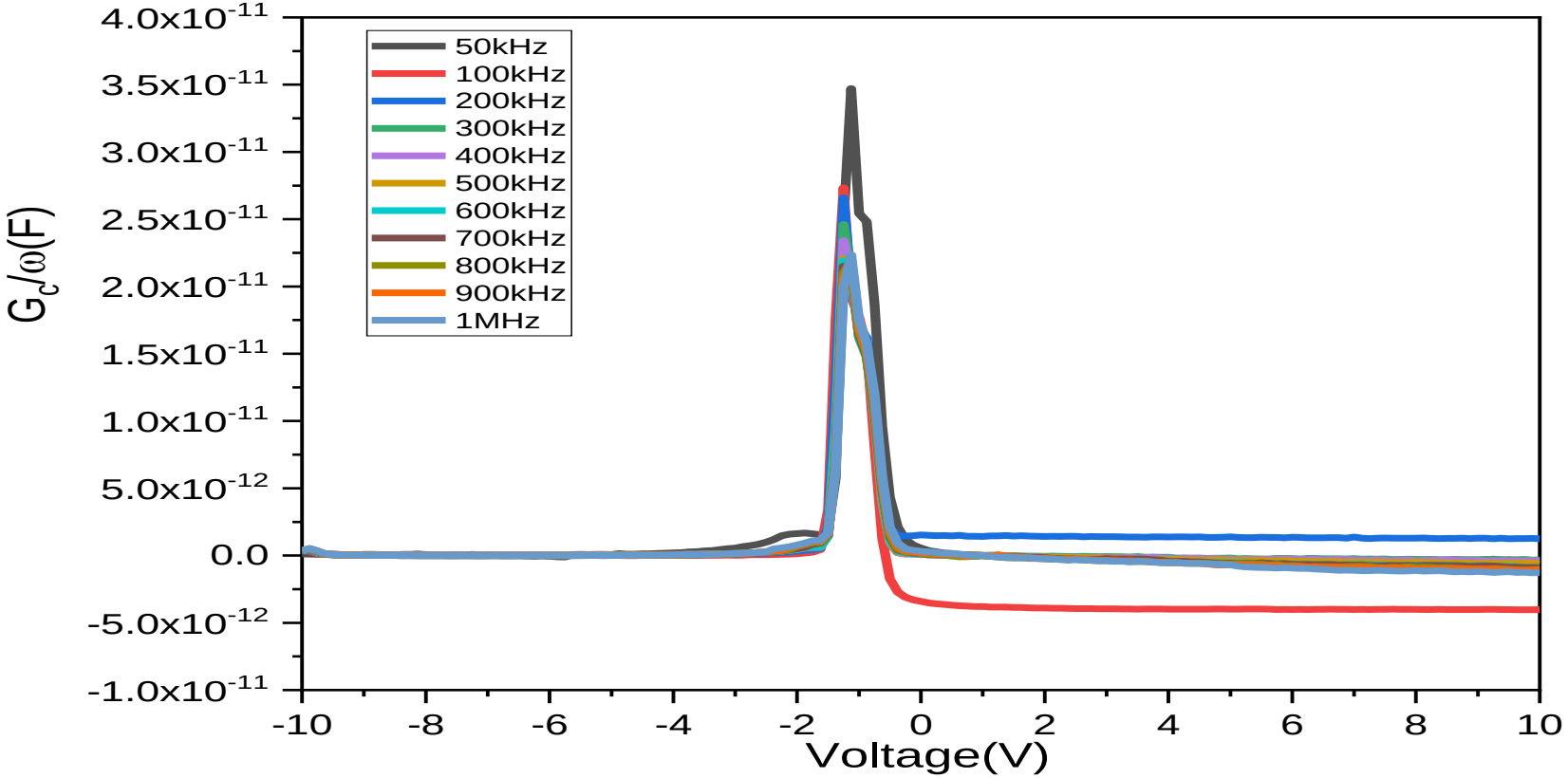


Figure.7 Corrected Conductance ($G_c/_w$) characteristics of Al/(Er_2O_3/SiO_2/n-Si/)Al MOS Capacitor for various frequency ranges from 50kHz to 1MHz

Frequency(kHz)	C_c(×10^{-9} F)	G_c/ω(×10^{-11}F)	R_s(Ω)	D_{it}(eV^{-1} cm^{-2})
50	1.43	3.42	900	2.46×10^{11}
100	1.36	2.65	398	3.02×10^{11}
200	1.30	2.59	217	4.85×10^{11}
300	1.27	2.40	161	6.11×10^{11}
400	1.25	2.32	130	7.42×10^{11}
500	1.23	2.19	111	9.15×10^{11}
600	1.21	2.17	100	1.22×10^{12}
700	1.21	2.16	91.0	1.22×10^{12}
800	1.20	2.16	85.0	1.44×10^{12}
900	1.19	2.14	77.0	1.71×10^{12}
1000	1.19	2.13	75.0	1.71×10^{12}

Table.1 Electrical parameters of E-beam Al(/Er_2O_3/SiO_2/n-Si)Al MOS capacitor

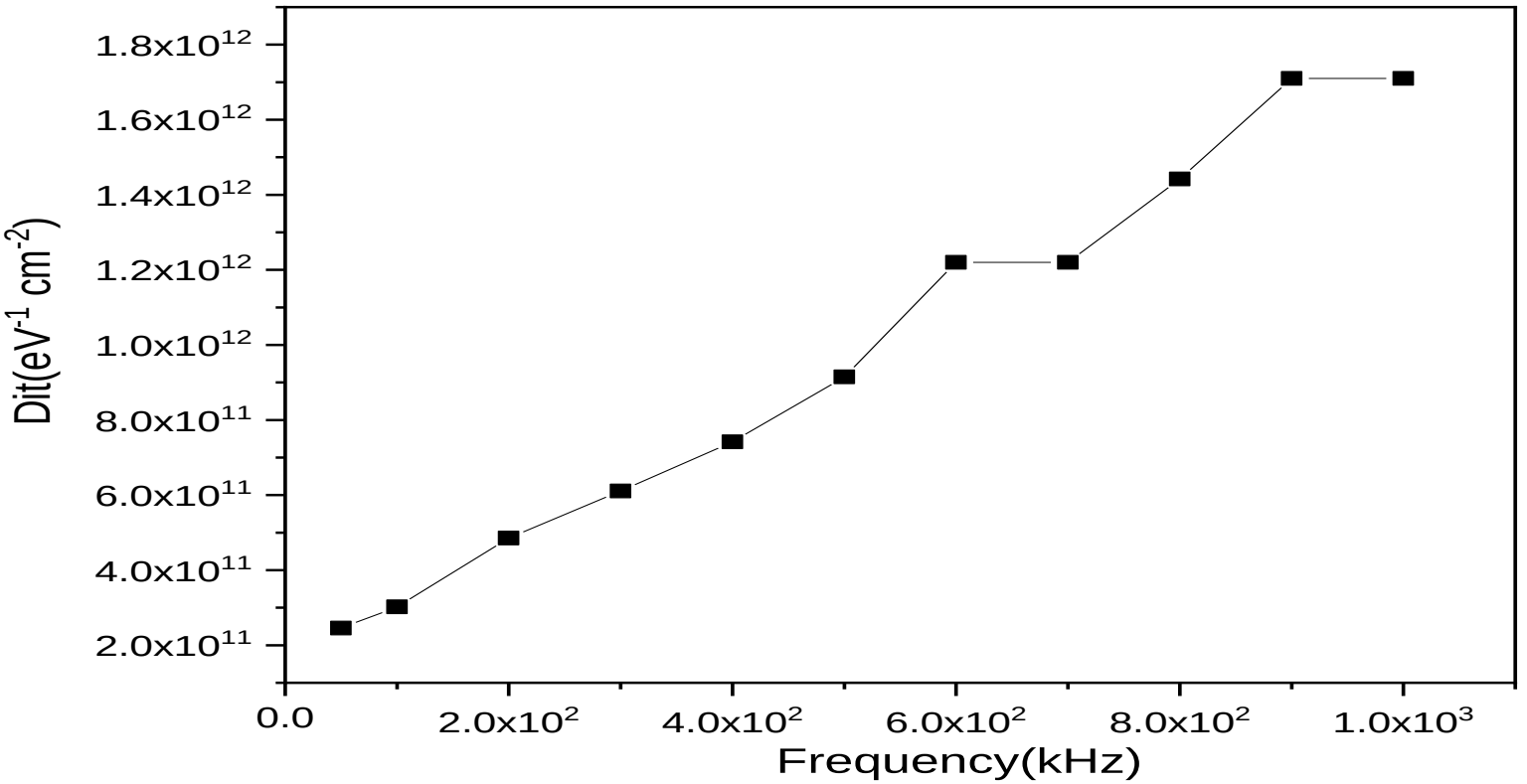


Figure.8 Variations of D_{it} as a function of frequency for Al/(Er_2O_3/SiO_2/n-Si)/Al MOS capacitor

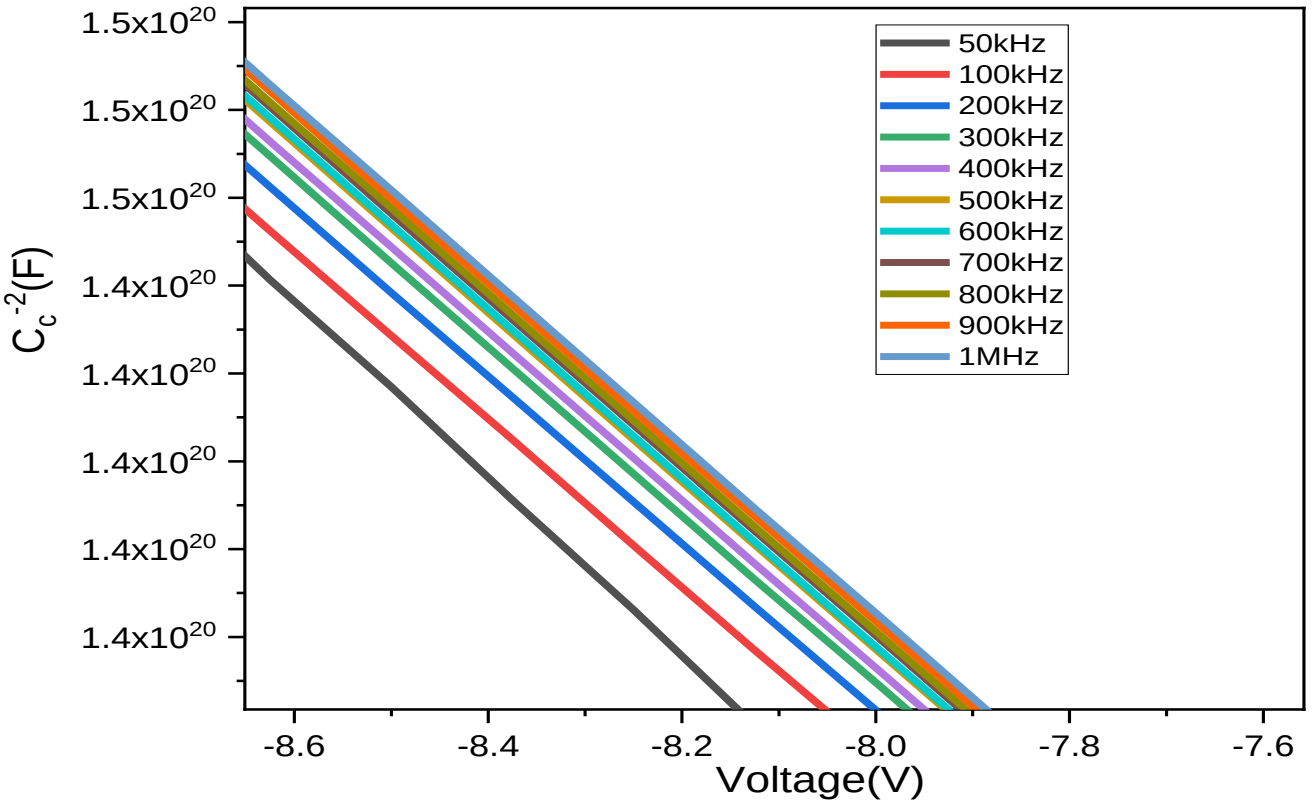


Figure.9 C_c^{-2}-V characteristics and corresponding linear fit function of Al/(Er_2O_3/SiO_2/n-Si) Al MOS capacitor at various frequency ranges from 50kHz to 1MHz

Frequency(kHz)	V_o(V)	V_D(eV)	E_F(eV)	$\Delta\Phi_B$(meV)	Φ_B(eV)	N_D(10^{15}cm^{-3})	W_D(10^{-5} cm)
50	1.490	1.470	0.250	18.50	1.230	1.87	0.20
100	0.974	0.948	0.249	16.90	0.716	1.99	7.92
200	0.953	0.927	0.249	16.80	0.695	1.99	7.83
300	0.943	0.917	0.249	16.80	0.685	1.98	7.81
400	0.935	0.909	0.249	16.70	0.677	1.98	7.77
500	0.925	0.899	0.249	16.70	0.667	1.97	7.75
600	0.921	0.895	0.249	16.60	0.663	1.97	7.73
700	0.912	0.886	0.249	16.60	0.653	1.97	7.69
800	0.909	0.883	0.249	16.60	0.651	1.97	7.68
900	0.906	0.880	0.249	16.60	0.648	1.97	7.67
1000	0.904	0.878	0.249	16.60	0.646	1.97	7.66

Table.2 Electrical parameters of Al/(Er_2O_3/SiO_2/n-Si)/Al MOS capacitor obtained from C_c^{-2}-V

CONCLUSION

The Al /Er_2O_3/SiO_2/n-Si/Al MOS capacitor was fabricated by using E-beam technique. The electrical characteristics of the prepared MOS capacitor were investigated in detail. The C-V and G/ω-Vmeasurements are indicated that measured capacitance and conductance are strongly dependent on the applied voltage frquency. Furthermore, C-V and G/ω-V characteristics of MOS capacitor have been controlled by the interfacial oxide layer, interface states and series resistance which are responsible for the non-ideal behaviour electrical characteristics.

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THANK YOU FOR YOUR ATTENTION!