

**RESISTIVE SWITCHING PROSPECTS OF
ALOE VERA-BASED THIN FILMS FOR
NONVOLATILE MEMORY APPLICATION**

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**RESISTIVE SWITCHING PROSPECTS OF
ALOE VERA-BASED THIN FILMS FOR
NONVOLATILE MEMORY APPLICATION**

by

LIM ZHE XI

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requirements for the degree of
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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	xv
LIST OF SYMBOLS	xx
ABSTRAK	xxiii
ABSTRACT	xxv
CHAPTER ONE: INTRODUCTION	
1.1 Overview of Electronic Memories	1
1.2 Emerging Nonvolatile Memories	3
1.3 Resistive Random-Access Memories	4
1.4 Aloe Vera Gel as Electronic Materials	7
1.5 Problem Statements	8
1.6 Research Objectives	9
CHAPTER TWO: LITERATURE REVIEW	
2.1 Resistive Switching	10
2.2 Resistive Switching Materials	13
2.2.1 Inorganic Materials	13
2.2.2 Organic Materials	17
2.2.3 Bio-Organic Materials	20

2.2.4	<i>Aloe Vera</i> Gel	22
2.3	Electrode Materials	26
2.4	Switching Mechanisms	29
2.4.1	Driving Force	29
2.4.2	Mobile Charge Species	31
2.4.3	Switching Region	32
2.4.4	Physicochemical Process	33
2.5	Switching Dynamics	42
2.5.1	Effects of Current Compliance	43
2.5.2	Effects of Voltage Sweep Rate	45
2.6	Conductance Quantization in Resistive Switching	46
2.8	Summary	53

CHAPTER THREE: MATERIALS & METHODOLOGIES

3.1	Materials	55
3.1.1	Natural <i>Aloe Vera</i> Gel	55
3.1.2	<i>Aloe</i> Polysaccharides	55
3.1.3	Top Electrode Materials	56
3.1.4	Substrate Materials	56
3.2	Methodologies	57
3.2.1	<i>Aloe Vera</i> Gel Extraction	58
3.2.2	Polysaccharides Extraction	58
3.2.3	<i>Aloe Vera</i> Gel Device Fabrication	59
3.2.4	Polysaccharides Device Fabrication	60
3.3	Characterization Techniques	61
3.3.1	Thermal Analysis	61

3.3.2	Surface Topography	62
3.3.3	Fourier Transform Infrared Spectroscopy	62
3.3.4	Film Thickness and Optical Constant Measurement	63
3.3.5	Transmission Electron Microscopy	64
3.3.6	Time-of-Flight Secondary Ion Mass Spectroscopy	64
3.3.7	X-Ray Photoelectron Spectroscopy	65
3.3.8	Electrical Characterization	65

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1	Aloe Vera Gel-Based Resistive Random-Access Memories	66
4.1.1	Thermal Analysis of Aloe Vera Gel	66
4.1.2	Effects of Ethanol on Film Formation	70
4.1.3	Effects of Drying Temperature on Film Formation	71
4.1.4	Effects of Drying Temperature on Film Optical Properties	72
4.1.5	Effects of Drying Temperature on Resistive Switching	75
4.1.6	Switching Mechanisms of Aloe Vera Gel-Based Device	78
4.1.7	Effects of Ethanol Concentration on Resistive Switching	86
4.1.8	Performance of Aloe Vera Gel-Based Device	88
4.1.9	Effects of Top Electrodes on Resistive Switching	96
4.2	Aloe Polysaccharides-Based Resistive Random-Access Memories	103
4.2.1	Thermal Analysis of Aloe Polysaccharides	103
4.2.2	Surface Topology of Aloe Polysaccharides Film	106
4.2.3	Electronic Switching Characteristics	111
4.2.4	Electrochemical Switching Characteristics	119
4.2.5	Thermochemical Switching Characteristics	130
4.2.6	Performance of Aloe Polysaccharides Device	134

4.3	Dynamics of Electrochemical Switching	135
4.3.1	Effects of Current Compliance on Switching Dynamics	135
4.3.2	Effects of Voltage Sweep Rate on Switching Dynamics	140
4.4	Conductance Quantization	143
CHAPTER FIVE: CONCLUSION		
5.1	Conclusion	149
5.2	Recommendations for Future Works	150
REFERENCES		152
LIST OF PUBLICATIONS		

LIST OF TABLES

		Page
Table 1.1	Comparison of key performances between existing and emerging memory devices (Semiconductor Industry Association, 2015).	3
Table 2.1	Review papers on resistive switching in MIM structures sorted according to year of publication.	11
Table 2.2	Resistive switching behaviors in MIM structures based on inorganic materials.	15
Table 2.3	Resistive switching behaviors in MIM structures based on organic materials.	18
Table 2.4	Resistive switching behaviors in MIM structures based on bio-organic materials.	21
Table 2.5	Phytochemical composition of <i>A. vera</i> gel.	23
Table 2.6	Protocols and optimal temperature for dehydration of <i>A. vera</i> gel.	25
Table 2.7	Examples of RRAMs with different electrodes materials.	27
Table 2.8	Switching mechanism of bio-organic RRAMs.	34
Table 2.9	Electronic processes in bio-organic devices (Ling et al., 2008).	37
Table 2.10	Conductance quantization in MIM structures.	48
Table 3.1	Materials evaporated as TEs of the devices.	56
Table 4.1	Weight loss characteristics of the gel with different ethanol concentrations.	67
Table 4.2	Origins and molecules associated to the FTIR transmittance peaks.	74

LIST OF FIGURES

		Page
Figure 1.1	Types of electronic memory devices.	1
Figure 1.2	Memory hierarchy in modern electronics.	2
Figure 1.3	(a) Vertical and (b) planar MIM structures; (c) Passive crossbar array; (d) 3D crossbar arrays (Lee et al., 2015b).	5
Figure 1.4	(a) Unipolar and (b) bipolar switching characteristics.	6
Figure 2.1	Classification of resistive switching materials.	13
Figure 2.2	(a) Typical <i>A. vera</i> plant; (b) Cross-section of <i>A. vera</i> leaf; (c) Optical microscope image and close-up illustration of the parenchyma tissues (Ni et al., 2004).	22
Figure 2.3	Chemical structures of (a) acemannan and (b) pectin extracted from natural <i>A. vera</i> gel (Chow et al., 2005).	24
Figure 2.4	Electric fields and Joule heating as the driving forces.	30
Figure 2.5	Charge migration due to (a) potential gradient, (b) momentum transfer, (c) temperature gradient, and (d) concentration gradient effects (Yang et al., 2013b).	31
Figure 2.6	Resistance changes in the a MIM structure (Lee et al., 2015b).	32
Figure 2.7	Electronic structure of an (a) atom, (b) bio-organic molecule, and (c) bio-organic solid; (d) Simplified energy band diagram of a bio-organic solid (Ishii et al., 1999).	35
Figure 2.8	Simplified energy diagram of electronic processes in MIM structures (Wong et al., 2012).	36
Figure 2.9	(a) $I-V$ characteristics of a hemolymph-based bio-organic; Curve-fitting of the $I-V$ characteristics in (b) HRS and (c) LRS (Wang & Wen, 2017).	38
Figure 2.10	$I-V$ characteristics and electrochemical switching processes of a chitosan-based bio-organic device (Raeis-Hosseini & Lee, 2015)	40
Figure 2.11	(a) TEM image of a gelatin-based device; (b) $I-V$ characteristics of the device; EDX mapping on the HAADF STEM images of the device in its (c) pristine conditions and (d) after resistive switching (Chang & Wang, 2014).	41

Figure 2.12	Effects of I_{CC} on (a) I - V characteristics, (b) endurance cycles, and (c) retention intervals of a sericin-based device (Wang et al., 2013a).	44
Figure 2.13	Effects of I_{CC} on R_{LRS} of a device based on SiO_2 (Bernard et al., 2011).	44
Figure 2.14	(a) I - V characteristics of a GeS_x -based device measured at different voltage sweep rates; (b) Effects of voltage sweep rate on VSET (van den Hurk et al., 2015).	45
Figure 2.15	(a) Conductance quantization observed in the HfO_2 -based device; (b) Conductance plot; (c) Evolution of the quantized conductance levels; (d) Histogram of normalized conductance levels (Long et al., 2013).	49
Figure 2.16	(a) Quantized conductance levels observed in a SiO_x -based device; (b) Histogram of the quantized conductance levels (Mehonic et al., 2013).	50
Figure 2.17	Quantized conductance at varying sweep rates (Younis et al., 2014).	51
Figure 2.18	Conductance quantization in a current sweep (Tappertzhofen et al., 2012).	52
Figure 2.19	Conductance quantization behaviors of a Ta_2O_5 -based device observed during the (a) SET and (b) RESET operations (Chen et al., 2013b)	52
Figure 3.1	Overview of the research flow.	57
Figure 3.2	Cross-sectional schematics of the fabricated MIM structure.	60
Figure 3.3	The process of turning an <i>A. vera</i> plant into a memory device.	61
Figure 4.1	Weight-loss characteristics of natural <i>A. vera</i> gel heated at different rates.	67
Figure 4.2	Weight-loss characteristics of natural <i>A. vera gel</i> with different ethanol concentrations.	68
Figure 4.3	Structural changes of pectin chains due to heating: (a) de-esterification (Massiot et al., 1997), (b) hydrolysis (Femenia et al., 2003), and (c) β -elimination (Chang et al., 2006).	69
Figure 4.4	De-acetylation of acemannan (Rodríguez-González et al., 2011).	70

Figure 4.5	Effects of ethanol on film thickness at a constant drying temperature.	71
Figure 4.6	Effects of drying temperature on <i>A. vera</i> gel film thickness at a constant ethanol concentration of 60 wt%.	72
Figure 4.7	Effects of drying temperature on the refractive index of a film dried at a constant ethanol concentration of 60 wt%.	73
Figure 4.8	FTIR spectra of the <i>A. vera</i> gel film dried at different temperatures.	74
Figure 4.9	J - V characteristic of <i>A. vera</i> gel-based MIM structure.	76
Figure 4.10	Effects of drying temperature on resistive switching.	77
Figure 4.11	Linear fittings of the J - V characteristics in (a) reverse bias and (b) forward bias regions.	78
Figure 4.12	Energy band diagrams in the reverse bias regime.	80
Figure 4.13	Energy band diagram at flatband voltage.	81
Figure 4.14	Energy band diagrams in the forward bias regime.	82
Figure 4.15	Electron trap centers formed by pectin and acemannan.	84
Figure 4.16	Deep electron traps formed by de-esterified pectin and de-acetylated acemannan.	85
Figure 4.17	Shallow electron traps formed by decomposed pectin and acemannan.	86
Figure 4.18	Effects of drying temperature on resistive switching behaviors of the device with 20 wt% ethanol.	86
Figure 4.19	Effects of ethanol concentration on resistive switching.	87
Figure 4.20	Effects of ethanol concentration on switching voltages.	89
Figure 4.21	Effects of ethanol concentration on the read memory windows.	90
Figure 4.22	Effects of ethanol concentration and drying temperature on OFF- and ON-state current densities.	91
Figure 4.23	Effects of ethanol concentration and drying temperature on ON/OFF ratios.	91
Figure 4.24	Typical retention characteristic of <i>A. vera</i> gel-based device.	93

Figure 4.25	J - V characteristics revealing the endurance performance of <i>A. vera</i> gel-based device.	94
Figure 4.26	Variation of (a) switching voltages and (b) ON- and OFF-state current densities.	95
Figure 4.27	J - V characteristics of <i>A. vera</i> gel-based device with Al TE.	96
Figure 4.28	J - V characteristics of <i>A. vera</i> gel-based device with Ag TE.	97
Figure 4.29	Linear curve-fitting of the J - V characteristics of the device with (a) Al and (b) Ag top electrodes in the positive bias region.	98
Figure 4.30	Linear curve-fitting of the J - V characteristics of the device with (a) Al and (b) Ag top electrodes in the negative bias region.	98
Figure 4.31	Effects of the cell area on resistance.	99
Figure 4.32	Effects of drying temperature on (a) ON/OFF ratio and (b) read memory windows of the <i>A. vera</i> gel-based device.	100
Figure 4.33	Filament formation, rupture, and reformation processes.	101
Figure 4.34	Effects of top electrode on retention characteristics.	102
Figure 4.35	Effects of top electrode on endurance cycles.	102
Figure 4.36	Effects of top electrode on the switching voltages.	103
Figure 4.37	TG and DTG profiles of the <i>A. polysaccharides</i> .	104
Figure 4.38	DSC profile of the <i>A. polysaccharides</i> .	104
Figure 4.39	FTIR spectra of the polysaccharides film.	105
Figure 4.40	Tapping mode AFM topography and phase images of the polysaccharides film dried at (a) 50°C, (b) 80°C, (c) 120°C, (d) 150°C, and (e) 180°C.	107
Figure 4.41	Effects of drying temperature on surface roughness of the polysaccharides film.	108
Figure 4.42	Effects of drying temperature on the polysaccharides film thickness. Inset shows the cross-sectional image of the film dried at 120°C.	109
Figure 4.43	Refractive index of the polysacchrides films.	110

Figure 4.44	Extinction coefficient of the polysaccharides films.	110
Figure 4.45	I - V characteristics of the polysaccharides device initiated with a negative voltage sweep.	111
Figure 4.46	I - V characteristics of the device with a permanent breakdown when the third voltage sweep is performed without I_{CC} .	112
Figure 4.47	Linear fittings on the I - V characteristics during (a) SET and (b) RESET operation.	113
Figure 4.48	Variation of polysaccharides film resistance as a function of device area.	114
Figure 4.49	I - V characteristics of the polysaccharides device with (a) Al, (b) Ag, (c) Cu, (d) Mg, and (e) Au as the top electrode.	115
Figure 4.50	Effects of top electrode on the switching voltages.	115
Figure 4.51	Effects of top electrode on device current.	116
Figure 4.52	Charge conduction processes during resistive switching.	117
Figure 4.53	Variation of (a) V_{RESET} and (b) I_{HRS} as a function of work function difference between TE and BE.	118
Figure 4.54	Cross-sectional TEM images of the polysaccharides/BE interface.	119
Figure 4.55	I - V characteristics of the polysaccharides device initiated with a positive voltage sweep.	120
Figure 4.56	I - V characteristics of the polysaccharides device without permanent device breakdown.	121
Figure 4.57	Electrochemical formation and dissolution of a filament.	122
Figure 4.58	Full logarithmic plots with linear fittings on the I - V characteristics during (a) FORM and (b) RESET operations.	123
Figure 4.59	Effects of device area on the resistance states.	124
Figure 4.60	I - V characteristics of the polysaccharides device with (a) Al, (b) Ag, (c) Cu, (d) Mg, and (e) Au as the TE.	125
Figure 4.61	Relationships between switching voltages and TEs.	125
Figure 4.62	V_{FORM} as a function of E° for various TEs.	126

Figure 4.63	Cross-sectional TEM images of devices with (a) Al, (b) Ag, and (c) Au TEs and the corresponding EDS line scan profiles.	127
Figure 4.64	TOF-SIMS depth profiles of the device with different TEs.	129
Figure 4.65	Unipolar switching exhibited by the polysaccharides device with Au TE.	130
Figure 4.66	Endurance cycles of the polysaccharides device with Au TE.	131
Figure 4.67	Variation of film resistance as a function of device areas.	131
Figure 4.68	Thermochemical formation and rupture a conductive carbon filament.	132
Figure 4.69	C1s core-level XPS spectra acquired in the (a) HRS and (b) LRS.	133
Figure 4.70	Percentage of carbon sp^2 hybridization in HRS and LRS.	134
Figure 4.71	Performance comparisons between the polysaccharides device and other bio-organic devices.	135
Figure 4.72	Effects of I_{CC} on resistive switching of the polysaccharides device.	136
Figure 4.73	Effects of I_{CC} on V_{FORM} of the polysaccharides device with different TEs.	136
Figure 4.74	Effects of I_{CC} on (a) V_{SET} and (b) V_{RESET} .	137
Figure 4.75	Effects of I_{CC} on I_{RESET} .	138
Figure 4.76	Effects of I_{CC} on R_{LRS} .	139
Figure 4.77	Effects of ν on resistive switching of the polysaccharides device.	140
Figure 4.78	Effects of ν on V_{FORM} .	141
Figure 4.79	Effects of ν on (a) V_{SET} and (b) V_{RESET} .	141
Figure 4.80	Effects of ν on R_{LRS} .	142
Figure 4.81	Effects of ν on I_{RESET} .	143
Figure 4.82	(a) Current response during SET operation measured with constant 1 V. (b–f) Filament regrowth process during the SET operation.	144

Figure 4.83	(a) Conductance quantization in the $I-V$ characteristics. Conductance quantization during the (b) SET and (c) RESET operations.	145
Figure 4.84	Current step response measured with a constant 6 V.	146
Figure 4.85	Conductance quantization in (a) FORM, (b) SET, and (c) RESET observed under voltage pulses.	147
Figure 4.86	Histograms of quantized conductance levels of the polysaccharides device with Ag and Cu TEs.	148
Figure 4.87	Histograms of quantized conductance levels of the polysaccharides device with Al and Mg TEs.	148

LIST OF ABBREVIATIONS

2D	Two dimension
3D	Three dimension
6F-BAHP-PC PI	Poly[2,2-(4,4'-di(N-benzyloxycarbazole)-3,3'-biphenylene)propane-hexafluoro-isopropylidenedipthalimide]
6F-HAB-CBZ PI	Poly[3,3'-bis(N-ethylenyloxycarbazole)-4,4'-biphenylenehexafluoro-isopropylidenedipthalimide]
8HQ	8-hydroxyquinoline
<i>A. vera</i>	<i>Aloe barbadensis</i> Miller
a-C	Amorphous carbon
AFM	Atomic force microscopy
AIDCN	2-amino-4,5-imidazoledicarbonitrile
AIR	Alcohol insoluble residue
ALD	Atomic layer deposition
Alq ₃	Tris(8-hydroxyquinolinato) aluminium
a-Si	Amorphous silicon
BE	Bottom electrode
BEOL	Back-end of line
BPhen	Bathophenanthroline
C ₆₀	Fullerene
CBRAM	Conductive bridging random-access memory
CNP	Cellulose nanofiber paper
CNT	Carbon nanotube
CTMA	Cetyltrimethylammonium
Cu:TCNQ	Cu:7,7,8,8-tetracyanoquinodimethane
CVD	Chemical vapor deposition

DCJTB	4-(dicyanomethylene)-2-t-butyl-6-(1,1,7,7-tetramethyljulolidyl-9-enyl)-4H-pyran
DI	Deionized water
DNA	Deoxyribonucleic acid
DRAM	Dynamic random-access memory
DSC	Differential scanning calorimetry
DT	1-dodecanethiol
DTG	Derivative thermal gravimetry
e-beam	Electronic beam
ECM	Electrochemical metallization cell
EDX	Energy dispersive X-ray
E-field	Electric field
ESA	Electrostatic self-assembly
FORM	Electroforming operation
FPA	Ferrocenylphenyl
FRAM	Ferroelectric random-access memory
FTIR	Fourier transform infrared
GNF	Graphene nanoflake
GO	Graphene oxide
HAADF	High-angle annular dark field
hBN	Hexagonal boron nitride
HDD	Hard disk drive
HOMO	Highest occupied molecular orbital
HRS	High-resistance state
ITO	Indium tin oxide

<i>I</i> - <i>V</i>	Current–voltage characteristics
J-heating	Joule heating
<i>J</i> - <i>V</i>	Current density–voltage characteristics
LB	Langmuir-Blodgett
LRS	low-resistance state
LTP	long-term potentiation
LUMO	Lowest unoccupied molecular orbital
MBE	Molecular beam epitaxy
MEH-PPV	Poly(2-methoxy-5(2'-ethyl) hexoxy-phenylenevinylene)
MIM	Metal-insulator-metal structure
NP	Nanoparticle
NPB	<i>N,N'</i> -di(naphthalene-1-yl)- <i>N,N'</i> -diphenyl-benzidine
NR	Nanorod
P3HT	Poly(3-hexylthiophene)
PARA	Poly(<i>O</i> -anthranilic acid)
PBD	2-(4-tert-butylphenyl)-5-(4-biphenyl)-1,3,4-oxadiazole
PCBM	(6,6)-phenyl C61-butyric acid methyl ester
PCRAM	Phase-change random-access memory
PCzMA	Poly(2-(<i>N</i> -carbazolyl)ethyl methacrylate)
PEDOT:PSS	Poly polystyrene sulfonate
PEO	Polyethylene oxide
PKEu	Poly[<i>N</i> -vinylacrbazole-co-Eu(vinylbenzoate)-(2-thenoyltifluoroacetone)2phenanthroline]
PLD	Pulsed laser deposition
PMC	Programmable metallization cell
PMMA	Polymethyl methacrylate

PPF	Paired-pulse facilitation
PS	Polystyrene
PTP	Post-tetanic potentiation
PVA	Polyvinyl alcohol
PVK	Poly(9-vinylcarbazole)
PVP	Polyvinylpyrrolidone
RAID	Redundant array of independent disk
rGO	Reduced graphene oxide
RRAM	Resistive random-access memory
SCLC	Space-charge-limited conduction
SEM	Scanning electron microscopy
SRAM	Static random-access memory
SSD	Solid-state drive
STDP	Spike-timing-dependent plasticity
STEM	Scanning transmission electron microscopy
STP	Short-term plasticity
STT-MRAM	Spin-torque-transfer magnetic random-access memory
TE	Top electrode
TEM	Transmission electron microscopy
TG	Thermal gravimetry
TMV	Tobacco mosaic virus
TOF-SIMS	Time-of-flight secondary ion mass spectroscopy
TPDBCN	bis{4-[4-[di(<i>p</i> -tolyl)amino]phenyl]phenyl} fumaronitrile
TTF	Tetrathiafulvalene
UV	Ultraviolet

VL	Vacuum level
WORM	Write-once read-many
WPF-oxy-F	Poly[(9,9-bis((6'-(<i>N,N,N</i> -trimethylammonium)hexyl)-2,7-fluorene)-alt-(9,9-bis(2-(2-methoxyethoxy)ethyl)-fluorene)] dibromide
XPS	X-Ray photoelectron spectroscopy

LIST OF SYMBOLS

$\Delta\phi$	Work function mismatch
μ	Charge mobility
A	Cell area
d	Thickness
e	Electronic charge
e^-	Electron
E°	Standard electrode potential
E_a	Trap activation energy
E_b	Schottky barrier height
E_c	Conduction band
E_t	Trap barrier height
E_{vac}	Energy of vacuum level
F	Minimal feature size of process technology
G_0	Quantum conductance
h	Planck's constant
I_{CC}	Current compliance
I_e	Electronic current
I_{G0}	Current at quantum conduction
I_{HRS}	HRS current
I_{ion}	Ionis current
I_{LRS}	LRS current
I_{RESET}	RESET current
J	Current density
J_{Child}	Current density due to Child-Langmuir law

J_{Mott}	Current density due to Mott-Gurney law
J_{Ohm}	Current density due to Ohm's law
k	Extinction coefficient
k_B	Boltzmann's constant
m	Charge mass
m^*	Effective mass
N	Density of states
n	Refractive index
n_0	Intrinsic charge density
n_e	Electronic concentration
N_t	Density of traps
q	Coulombic charge
r	Radius of cylindrical filament
R_0	Resistance of single-atomic contact
R_a	Average roughness
R_{HRS}	HRS resistance
R_{LRS}	LRS resistance
R_{rms}	Root-mean-square roughness
T	Temperature
V	Applied voltage
V_{FORM}	FORM voltage
V_O	Oxygen vacancy
V_{READ}	READ voltage
V_{RESET}	RESET voltage
V_{SET}	SET voltage

$Z(x)$	Height profile function
ε	Dielectric constant
ε_0	Permittivity of free space
ε_r	Relative permittivity
λ	Reflected wavelength
ν	Voltage sweep rate
σ	Conductivity
τ_i	Eigenvalue of i -th transmission channel

PENSUISAN RINTANGAN PROSPEK FILEM NIPIS BERDASARKAN ALOE VERA UNTUK APLIKASI SEBAGAI MEMORI TIDAK MERUAP

ABSTRAK

Pensuisan rintangan ialah satu peralihan paradigma untuk memori tidak meruap. Fenomena ini ditunjuk melalui struktur MIM yang berlandaskan bahan bio-organik. *Aloe vera* merupakan sejenis penebat bio-organik yang berpotensi untuk aplikasi elektronik. Namun, pensuisan rintangan masih belum ditunjuk oleh peranti yang berdasarkan *Aloe vera*. Oleh itu, objektif pengajian ini adalah untuk membuktikan bahawa pensuisan rintangan boleh ditunjuk dengan struktur MIM yang berdasarkan jel *Aloe vera*. Peranti ini hanya mempamirkan pensuisan rintangan dwi-kutub jikalau jel tersebut dikeringkan pada suhu 50°C. Ia perlu dikeringkan dengan 20–60 wt% etanol untuk membolehkan pensuisan rintangan pada suhu lain. Mekanisme pensuisan boleh diterangi melalui arus berbatasan ruang-caj. Elektrod atasan mempunyai impak terhadap mekanisme pensuisan kerana pensuisan yang diperhatikan adalah juga dikaitkan dengan pengaliran filamen jikalau Ag atau Al digunakan sebagai elektrod atasan. Peranti tersebut mempamirkan prestasi yang bagus dengan tettingkap baca memori yang luas (~ 5 V), nisbah ON/OFF yang besar ($>10^5$), kitaran ketahanan yang panjang (>100 kitaran), dan tempoh pengekalan yang cemerlang ($\geq 10^4$). Acemannan dan pectin adalah punca pensuisan tersebut. Peranti berlandaskan polisakarida yang diekstrak mempamirkan kedua-dua se- dan dwi-kutub tergantung kepada elektrod atasan yang digunakan. Mekanisme peranti itu boleh dijelaskan oleh beberapa proses yang bersifat elektronik, elektrokimia, dan termokimia. Ia menyampaikan prestasi yang sangat baik, termasuk tettingkap baca memori selebar 5.2 V dan nisbah ON/OFF sebesar $\sim 10^7$. Selain itu, rintangan keadaan OFF peranti ini boleh dimodulasikan lebih daripada 5 perintah magnitude dengan I_{CC} dan v . Kuantisasi