ROCHESTER INSTITUTE OF TECHNOLOGY MICROELECTRONIC ENGINEERING

Humidity Sensor

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PRISM MEMS MULTISENSOR CHIP – VER 2



1-AxisAccelerometer Temperature Sensor Humidity Sensor Strain Sensor

Humidity Sensor finger overlap 2000um # of fingers 20 finger width 10 finger space 10 pad size 400 x 400 polyimide thickness

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VER 2 HUMIDITY SENSOR CALCULATIONS

Capacitance = eoer Area/d	o = Permitivitty of er = relative per umber of pairs of r distance between	C = free space rmitivitty = Area = plates, N =	2.72E-11 8.85E-14 3.9 3.15E-03	F F/cm cm2						Сu	s Humi	dity		
	o = Permitivitty of er = relative per umber of pairs of distance between	free space rmitivitty = Area = plates, N =	8.85E-14 3.9 3.15E-03	F/cm cm2			-							
	er = relative per umber of pairs of distance between	rmitivitty = Area = plates, N =	3.9 3.15E-03	cm2										
	umber of pairs of j distance between	Area = plates, N =	<u>3.15E-03</u>	cm2			-		11.00					
	umber of pairs of j distance between	plates, N =	1				-		10.00				_	
	distance between						_		9.00 -	+-+				
		plates, d =	0.4	μm			-		- 8.00					
	If round plates, I	Diameter =	0	μm			_		a					
	lf rectangular plate	s, length =	670	μm			-		§					
	If rectangular plate	es, width =	470	μm			-		8 800					
Force Between Two Paralle	<u>i Plates</u>	Force =	3.40E-03	N			-		ğ 200-					
<u>Electrostatic Force= eoer /</u>	Area Wipplind Vo	oltage, V =	10	volts			BH%	CpF	J 4.00					
							10	9.18	3.00 -					
Sapacitance for very Thick	Interdigitated	Fingers					20	9.26	2.00					
C = (N-1) eoer L M	s Capac	citance, C =	1.70E-12	F			30	9.35	1.00	ļ				
	Number of F	ingers, N =	121				40	9.43		0 70		60	20	
rel	ative dielectric cor	nstant, er =	8				50	9.51		0 20	40	80	20	10
	Length of finger (overlap, L =	100	μm			60	9.60			Relative H	ImfoIty %		
	height of	fingers, h =	2	μm			70	9.68						
	space between	fingers, s =	1	μm			80	9.77						
									zero order				_	
Capacitance for very Thin I	nterdigitated l	Fingers of	thick insula	ting sub	ostrate			(2n-1)(pi)s/2(s+w	Bessel			sum		
	Capad	citance, C =	1.83E-12	F	3.8	erTop	n	x	Jo(x)	Jo²	Jo ² /2n-1	0.77550	072	
$C = LN[4 \text{ s.c.}] \stackrel{\text{def}}{=} _ _ _ _ _ [Gr_1 \cup T_{T_1}]$	Number of F	ingers, N =	20		0	er Bottom	1	0.785	0.8518	0.7255	0.7255			
	ative dielectric cor	nstant, er =	5.24		60	BH%	2	2.355	0.0261	0.0007	0.0002			
	Length of finger (overlap, L =	2000	μm	5.24	er"	3	3.925	-0.401	0.1608	0.0322			
	width of f	fingers, w =	10	μm			4	5.435	-0.0086	7E-05	1E-05			
	space between	fingers, s =	10	μm			5	7.065	0.2998	0.0899	0.01			
If on oxide over sil	licon use equal	tion above	with eo for	materia	l above th	e fingers	6	8.635	0.0051	3E-05	2E-06			
added to	the Capacitanc	e to silico:	on substrate	calculat	ted below									
Capa	citance to Silicon S	Substrate =	7.77E-12	F			7	10.205	-0.2496	0.0623	0.0048			
	(er (oxide) =	3.9				8	11.775	-0.0038	1E-05	1E-06			
	Oxide	thickness =	8000	Å			9	13.345	0.2183	0.0477	0.0028			
Total area of pad	is and other layout	: features =	320000	um2			10	14.915	0.0033	1E-05	6E-07			
	Total Ca	pacitance =	9.60E-12	F										



Humidity Sensor PLANAR INTERDIGITATED SENSOR w 5 $C = (N-1)L\frac{(\varepsilon_{r1} + \varepsilon_{r2})\varepsilon_0 K[(1-k^2)^{\overline{2}}]}{2K(k)}$ $k = \cos\left(\frac{\pi}{2} \frac{w}{(s+w)}\right)$ d_1 d_2 $K(k) = \int_{0}^{1} \frac{1}{\sqrt{(1-t^2)(1-k^2t^2)}} dt$ ϵ_{r2} $\mathbf{C} = \mathbf{LN}\left(\underline{\mathbf{4}}_{\mathbf{g}_{0}} \mathbf{g}_{\mathbf{x}}\right) \sum_{n=1}^{\infty} \frac{1}{2n \cdot 1} J_{0}^{2} \left(\frac{(2n \cdot 1)\pi s}{2(s+w)}\right)$ $E_{r} = E_{r1} + E_{r2}$ Jo is zero order Bessel function **Rochester Institute of Technology** Microelectronic Engineering V.F.Lvovich, C.C.Liu, M.F.Smiechowski © March 28, 2011 Dr. Lynn Fuller, Professor Page 6





FILM CRACKING







Polyimide film if not cured correctly will crack as it absorbs water



PROPERTIES OF POLYIMIDE

Polyimide - Kapton, Apical, Upilex and other names. Polyimide films are available in differing chemistries with different properties. The curing and annealing cycles are important in defining film properties.

Stable to 400°C (and above without oxygen available)Relative Dielectric Constant3.0 to 3.7Water absorption (%)2.1 to 3.7CTE 100-200C (ppm/C)15 to 35CHE (ppm/%RH)10 to 20Youngs Modulus (Gpa)2.7 to 5.5



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CALCULATIONS FOR EXAMPLE

'			2 72E 44	F						-				
apacicance = eoer Are	acicance = eoer Areard U=		0.0000.14	Flor						- C 1	rs Humi	idity		
	eo = Permitivitty of	r free space	0.000-14	Frem								•		
	er = relative po		2.455.02						351.00					
	aumhar of pairs of	nistes Min	<u>3.15E-03</u>	Cm2					301.00			• • • •	-	
	dictorion batwoon	plates, M =	0.4		-		-							
	lf sound plates	Diamator -	0.4	ատ	-				- 2 51.00					
	If soctongular plates,	so longth -	670	<u>и</u> т.			-		8 101 00					
	If rectangular place	os, religin –	470	<u>и</u> т.			-		3 20100					
orce Between Two Pa	allel Plates	Eorce =	3 40E-03	M					§ 171.00					
actrostatic Forces av	A Area Window V	oltogo V a	10	nolte			DH2	CoF	a					
			10	VOICS			10	308.63	• 101.00					
anacitance for ears T	ick Interdigitated	Finders					20	309.41	51.00					
C = (N-1) ever L Ms Capacitance, C =			170E-12	F			30	310.19						
	Number of P	Finders N=	121				40	310.37	1.00	+	· · · ·		-	
	relative dielectric co	nstant, er a	8				50	311.74		0 2	20 40	60	20	10
	Length of finger	overlap I =	100	um			60	312.52						
	beight of	fingers ha		<u>и</u> т.	-		70	313.30			Kelative	HIMICITY 28		
	space between	fingers, s =	1	ստ			80	314.08						
				p.m.				014.00	zero order					
apacitance for vers T	in Interdigitated	Fingers on	thick incula	tina sul	hstrate			(2n-1)(ni)s/2(s+w	Bessel			cum		
		diana an Carl	1 705 11		2.0				1.4	1.2	1-212-1	0 52052	er.	
	Number of f	citance, C =	1.102-11	r		er i op	n 1	X 1 1775	0 6 9 9 2	0.4655	0.4655	0.55255	000	
$= IN[4gE_{r}] \sum_{2n=1}^{n} introduction (\frac{1}{2} + \frac{1}{2})$	I Number of I	ingers, iv =	5.04		60	DUN		2,5225	0.0023	0.4000	0.4655		_	
	exterior distanteia as		3.6.9		1 00	1 DUA	6	0.0020	-0.0044	0.1411	0.0402			
1 Miles (1997)	relative dielectric co	overlag, et al	5400		5.24		2	5 9 9 7 5	0.1193	0.014	0.00028			
	Length of finger	overlap, L =	5400	μm	5.24	er"	3	5.8875	0.1183	0.014	0.0028		_	
	Length of finger width of	overlap, L = fingers, w =	5400 10	μm μm	5.24	l <u>er"</u>	3 4	5.8875 8.2425 10.5975	0.1183	0.014	0.0028			
	Length of finger width of space between	overlap, L = fingers, w = fingers, s =	5400 10 30	μm μm μm	5.24	er"	3 4 5	5.8875 8.2425 10.5375 12.9525	0.1183 0.1112 -0.2279	0.014 0.0124 0.0519	0.0028 0.0018 0.0058			
If on oxide over	relative dielectric co Length of finger width of space between r silicon use equa	overlap, L = fingers, w = fingers, s = tion above	5400 10 30 with co for	μm μm materia	5.24	er' C	3 4 5 6	5.8875 8.2425 10.5975 12.9525	0.1183 0.1112 -0.2279 0.2033	0.014 0.0124 0.0519 0.0414	0.0028 0.0018 0.0058 0.0038			
If on oxide over	relative dielectric co Length of finger width of space between r silicon use equa to the Capacitan	overlap, L = fingers, w = fingers, s = tion above ce to silico Substrate =	5400 10 30 with co for substrate 2 36E-10	μm μm materia calculat	5.24	er"	3 4 5 6 7	5.8875 8.2425 10.5375 12.3525	0.1183 0.1112 -0.2273 0.2033	0.014 0.0124 0.0513 0.0414	0.0028 0.0018 0.0058 0.0038			
If on oxide over	relative dielectric co Length of finger width of space between r silicon use equa to the Capacitane Capacitance to Silicon	overlap, L = fingers, w = fingers, s = tion above te to silico Substrate = or (ovide) =	5400 10 30 with co for substrate 2.36E-10 39	μm μm materia calculat	5.24	er'	3 4 5 6 7	5.8875 8.2425 10.5975 12.9525 15.3075 17.6525	0.1183 0.1112 -0.2273 0.2033 -0.075 -0.0754	0.014 0.0124 0.0519 0.0414 0.0056 0.0056	0.0028 0.0018 0.0058 0.0038 0.0004			
If on oxide over	relative dielectric co Length of finger width of space between r silicon use equa to the Capacitane Capacitance to Silicon	overlap, L = fingers, w = fingers, s = tion above ce to silico Substrate = er [oxide] = tbickness =	5400 10 30 with co for substrate 2.36E-10 3.3 8000	μm μm materia calculat F	5.24	er'	3 4 5 6 7 8 9	5.8875 8.2425 10.5975 12.3525 15.3075 17.6625 20.0175	0.1183 0.1112 -0.2273 0.2033 -0.075 -0.0754 0.1658	0.014 0.0124 0.0519 0.0414 0.0056 0.0057 0.0275	0.0028 0.0018 0.0058 0.0038 0.0004 0.0004 0.0016			
If on oxide over	relative dielectric co Length of finger width of space between r silicon use equa to the Capacitant Capacitance to Silicon Oxide	overlap, L = fingers, w = fingers, s = tion above ce to silico Substrate = er (oxide) = thickness = thickness =	5400 10 30 with co for substrate 2.36E-10 3.3 8000 2200000	μm μm materia calculat F Å μm2	5.24	er'	3 4 5 6 7 8 9	5.8875 8.2425 10.5975 12.9525 15.3075 17.6625 20.0175 22.3725	0.1183 0.1112 -0.2279 0.2033 -0.075 -0.0754 0.1658 -0.1547	0.014 0.0124 0.0519 0.0414 0.0056 0.0057 0.0275 0.0239	0.0028 0.0018 0.0058 0.0038 0.0004 0.0004 0.0016 0.0013			



BETTER DESIGN

ouparitance - coor moard		C =	2.72E-11	F						CV	s Humi	iditv	
	eo = Permitivitty	of free space	8.85E-14	F/cm	- S.						• • • •	,	
	er = relative	e permitivitty =	3.9		1				91.00	1			
		Area =	3.15E-03	cm2					81.00				
	number of pairs	of plates, N =	1						74.00				
	distance betwe	en plates, d =	0.4	μm					/1.00				
	If round plate	es, Diameter =	0	μm					ዄ 61.00				
	If rectangular pl	ates, length =	670	μm	-				Ž 51.00				
	If rectangular p	lates, width =	470	μm			_		41 00				
Force Between Two Parallel	Plates	Force =	3.40E-03	Ň					8				
Electrostatic Force= eoer Ar	ea V ² /2d ² Applied	IVoltage, V = ∣	10	volts	2		RH%	CpF	ت 31.00				
							10	66.76	21.00				
Capacitance for very Thick I	nterdigitated Fir	ngers		12			20	69.18	11.00				
C = (N-1) eoer L h/s	: Car	pacitance, C =	2.82E-12	F			30	71.60					
	Number of Fingers, N =		200				40 74.02 50 76.45 60 78.87		1.00	i		1. 1.	
1	elative dielectric (8				0 2			40	60 80	10		
	Length of finge	100	μm						Relative Himidity %				
	height	2	μm			70	81.29						
	space betwee	en fingers, s =	1	μm			80	83.71 -					
						10			zero order				
Capacitance for very Thin In	terdigitated Fin	gers on thick in	nsulating sul	ostrate				(2n-1)(pi)s/2(s+	w Bessel	_		sum	
	Car	pacitance, C =	4.08E-11	F	3.8	er Top	n	x	Jo(x)	Jo ^z	Jo ^z /2n-1	0.89508275	
$C = LN[4 \pi_{e} E_{e}] \sum_{j=1}^{10} \frac{1}{2} \sqrt{(2n-1)\pi_{e}}$	Number o	of Fingers, N =	400		0	er Bottom	1	0.628	0.90381	0.81687	0.81687		
(<u></u>	elative dielectric constant, er =		4.04		10	RH%	2	1.884	0.29112	0.08475	0.02825		
	Length of finge	er overlap, L =	2500	μm	4.04	er*	3	3.14	-0.30379	0.09229	0.01846		
	width c	of fingers, w =	3	μm			4	4.396	-0.34307	0.11769	0.01681		
	space betwee	en fingers, s =	2	μm			5	5.652	0.04423	0.00196	0.00022		
If on oxide over sil	icon use equati	on above with	eo for mater	ial above	the finger	s	6	6.908	0.29837	0.08903	0.00809		
added to	the Capacitance	e to silicon sub	strate calcul	ated belo	w								
Ca	pacitance to Silico	on Substrate =	2.60E-11	F			7	8.164	0.13144	0.01728	0.00133		
		er (oxide) =	3.9				8	9.42	-0.18036	0.03253	0.00217		
		de thicknesse -	10000	A			9	10.676	-0.21932	0.0481	0.00283		
	Oxic	ae thickness =		-			40	44.022	0.03235	0.00105	5.5E-05		
Total area of pa	oxi Ids and other lays	out features =	12000	um2	2		10	11.852					
Total area of pa	ads and other layo	out features = Capacitance =	12000 6.68E-11	um2 F			10	11.332					
Total area of pa	ads and other layo Total (Closely Spaced)	out features = Capacitance = Wires	12000 6.68E-11	um2 F			10	11.332					
Total area of pa	Oxi ads and other layo Total Capacitance per u	ut features = Capacitance = Wires unit length, C =	12000 6.68E-11 63.47	um2 F pF/m			10	11.552					
Capacitance Between Two C Copacitance Copacitance Copacitance Determination of the Copacitance per unit length CL	ads and other layo Total Cosely Spaced 1 Capacitance per u elative dielectric o	capacitance = Capacitance = Wires unit length, C = constant, er =	12000 6.68E-11 63.47 3	um2 F pF/m			10	11.332					
Total area of particular area of	Oxi ads and other layo Total Capacitance per u elative dielectric o nalf center to cen	te trickitess = out features = Capacitance = Wires unit length, C = constant, er = ter space, h =	12000 6.68E-11 63.47 3 1	um2 F pF/m mm			10	11.332					
Total area of particular Capacitance Between Two (Capacitance per unit length CL C/L = 12.1 c _x / (log (h/x) + ((h/r) ² -1) ¹²) h = half center to center space r = conductor state (seare units or h)	Ads and other lays Total Total Capacitance per u elative dielectric of half center to cen conduct	ae trick less = but features = Capacitance = Wires unit length, C = constant, er = ter space, h = tor radius, r =	12000 6.68E-11 63.47 3 1 0.5	um2 F pF/m mm mm				11.332					









HUMIDITY SENSOR AND BLUE TOOTH WIRELESS



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