An Implantable Pressure Sensor for Aneurysmal Disease

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Background of Abdominal Aortic Aneurysms (AAA)

- The natural history of AAA's is one of progressive enlargement over time as a result of tension related to passive dilation from hemodynamic forces, and a complex remodeling process involving the aortic wall that leads to a focal loss of elastic tissue
- The ultimate result of this progression is rupture of the AAA producing serious and even lethal consequences.

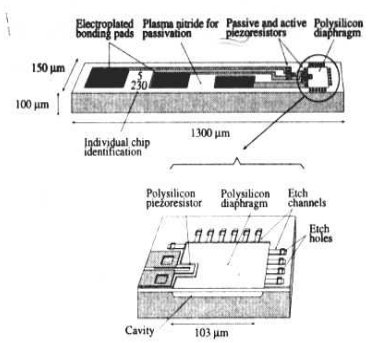
- The incidence of AAA in the general population is 36/100,000 and 60/100,000 in the age-related population
- In 1988, there were 40,000 AAA repairs in the U.S., and AAA rupture killed 15,000 people making it the 13th leading cause of death
- A new minimally invasive approach for the repair of AAA's uses endovascular techniques to place an intraluminal stent-anchored prosthetic graft within an aneurysm, effectively excluding the aneurysm from normal circulation

Implantable Pressure Sensor (IPS)

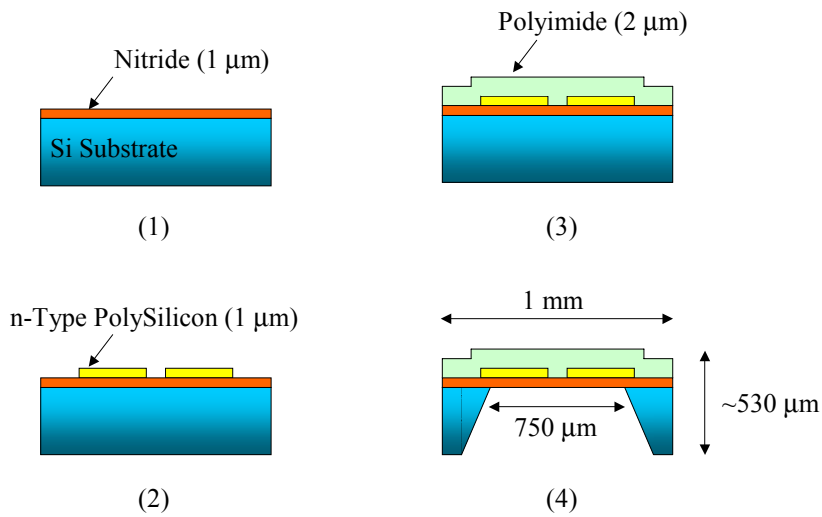
- An IPS will be able to detect and alert the surgeon of elevations in pressure in the excluded aneurysmal sac
  - » enabling evaluation for backbleeders intra-op; and potentially decreasing the costs from expensive follow-up imaging studies
- An IPS will save $263 million in healthcare costs for AAA repair

Required Parameters

- Biocompatible
- Dimensions
  < 1 mm wide
- Range
  0-300 mm hg
- Operating temperature range
  35-40 °C
- Sensitivity
  1 mm hg increments
- Cost
  < $600/patient•year



Process Flow



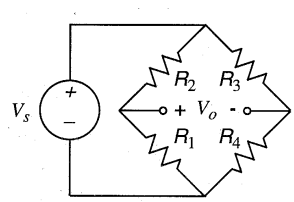
Relationship Between Pressure Input & Voltage Output

- Using a Wheatstone bridge

$$\frac{V_o}{V_s} = \frac{R_1R_3 - R_2R_4}{(R_1 + R_2)(R_3 + R_4)}$$

- Assuming R_1=R_3, R_2=R_4

$$\frac{V_o}{V_s} = \frac{R_1 - R_2}{R_1 + R_2} = \frac{\Delta R}{R} = -\varepsilon \times \text{gauge factor}$$



Strain of Circular Membrane From Roark's

$$\varepsilon = \frac{\Delta P}{E} \times \frac{3a^2}{8t^2} \times \left[(3+\upsilon)\left(\frac{r}{a}\right)^2 - (1+\upsilon) \right]$$

at $r = a$,

$$\Delta P = \frac{4Et^2V_m}{3 \times G.F. \times V_s \times a^2}$$

where

E = effective Young's modulus

$$= \frac{E_{Nitride} \times t_{Nitride} + E_{Polyimide} \times t_{Polyimide}}{t_{Nitride} + t_{Polyimide}}$$

$= 91.33 \text{ N/m}^2$

υ = effective Poisson's ratio (not needed)

V_S = supply voltage = 5 V

G.F. = gauge factor = 20

a = membrane radius = 375μm

r = distance from center

Conclusion

Parameter	Satisfied?	Comments
Biocompatible	Yes	Polyimide coating is compatible with body
Dimensions (< 1 mm wide)	Yes	1 mm wide
Range (0-300 mm Hg)	Yes	With a range of 0 - 3000 mm Hg
Op. Temp.Range (35-40 ^{o}C)	Yes	All materials operate in this temperature range
Sensitivity (1 mmHg increments)	Yes	1.7 mV/mm Hg
Cost	Yes	~ $150/patient•year