3.155J/6.152J
Microelectronic Processing
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NAME

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Quiz 2 3 Questions April 20, 2005

1. a) [3 pts] You want to sputter deposit an equi-atomic SiGe film from an equi-atomic SiGe target using an Ar plasma. What film composition will you get if you begin the deposition as soon as the plasma has reached equilibrium? Why?
b) [2 pts] What could you do to get the desired SiGe composition?

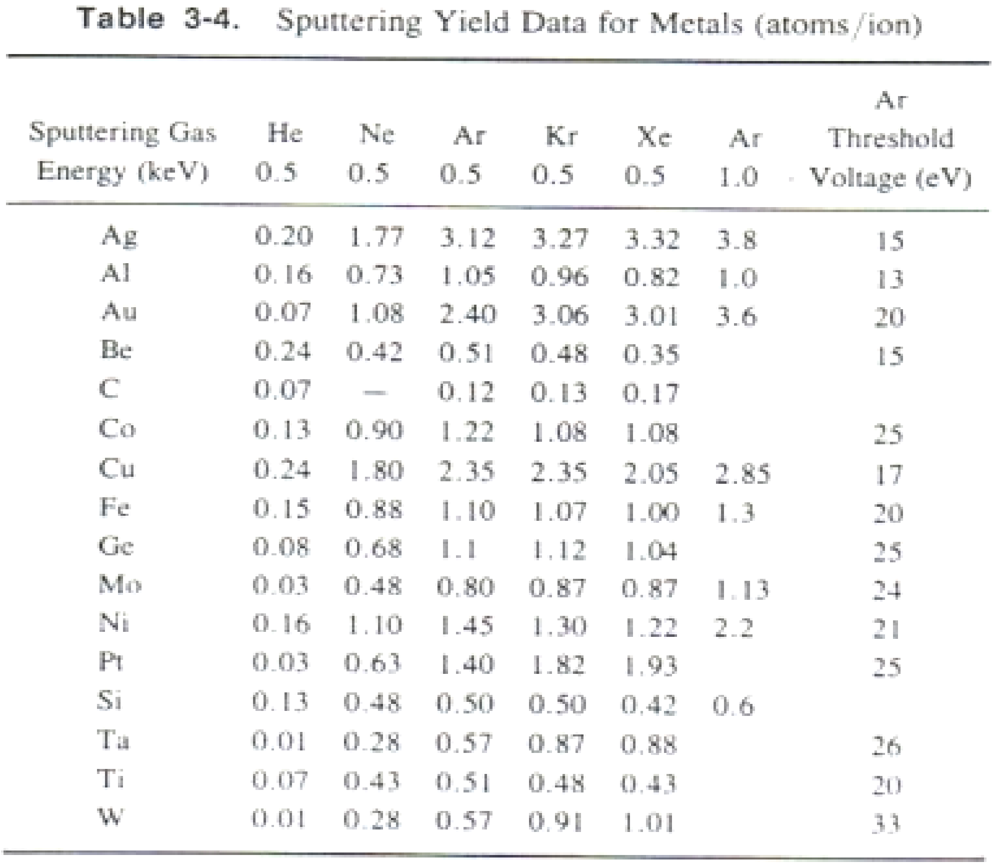


Table 3-4. Sputtering Yield Data for Metals (atoms/ion)

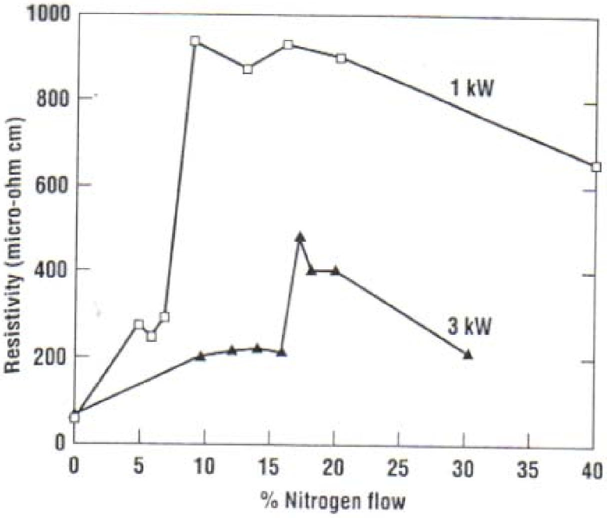
Sputtering Gas	He	Ne	Ar	Kr	Xe	Ar	Ar Threshold
Energy (keV)	0.5	0.5	0.5	0.5	0.5	1.0	Voltage (eV)
Ag	0.20	1.77	3.12	3.27	3.32	3.8	15
Al	0.16	0.73	1.05	0.96	0.82	1.0	13
Au	0.07	1.08	2.40	3.06	3.01	3.6	20
Be	0.24	0.42	0.51	0.48	0.35		15
C	0.07	—	0.12	0.13	0.17		
Co	0.13	0.90	1.22	1.08	1.08		25
Cu	0.24	1.80	2.35	2.35	2.05	2.85	17
Fe	0.15	0.88	1.10	1.07	1.00	1.3	20
Ge	0.08	0.68	1.1	1.12	1.04		25
Mo	0.03	0.48	0.80	0.87	0.87	1.13	24
Ni	0.16	1.10	1.45	1.30	1.22	2.2	21
Pt	0.03	0.63	1.40	1.82	1.93		25
Si	0.13	0.48	0.50	0.50	0.42	0.6	
Ta	0.01	0.28	0.57	0.87	0.88		26
Ti	0.07	0.43	0.51	0.48	0.43		20
W	0.01	0.28	0.57	0.91	1.01		33

Answers:
a) From the table below the sputter yield of Ge is 1.1 and that of Si is 0.5 so more than twice as much Ge is sputtered from the target as Si. The initial composition of the film will be $Ge_{69}Si_{31}$ (atom %).

b) You could do one of three things. 1) Keep a shutter over half your anode (protecting the good substrates) until enough time has passed to allow the surface composition of the target to approach a Si/Ge ratio ($Si_{69}Ge_{31}$) that would give the desired film composition. 2) Use a target covered with pure Si over 69% of its area and Ge over the remaining 31%. 3) Use separate sputtering targets at different potentials to give the desired film composition.

2. a) [2 pts] Explain the jump in the resistivity of the films produced when Ti is sputter deposited in flowing nitrogen at different rates as shown in the accompanying figure.

   b) [3 pts] Why does the jump in the resistivity for the 3 kW sputtering power occur at higher nitrogen flow than for 1 kW?

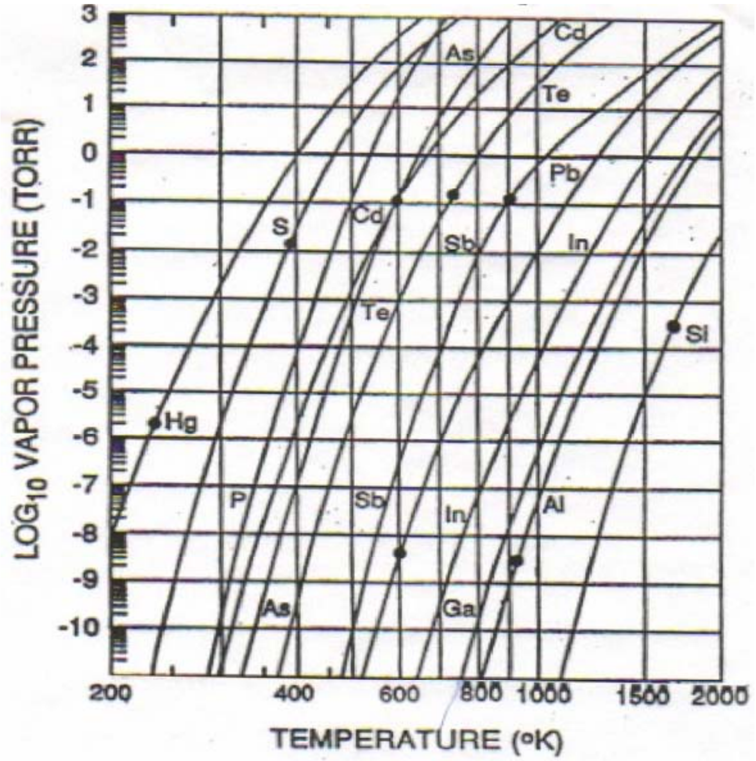


Answer: a) Resistivity is low when metallic Ti is deposited., but with enough flow you get TiN which is an insulator and hence has higher resistivity.
b) Higher RF power increases the Ti flux between the cathode and anode. In order to get enough nitrogen flow to form TiN, the flow rate has to increase.

3. You want to grow a Si (atomic weight 28 AMU) film by *thermal evaporation* of Si at a total pressure of 2 x 10^{-7} Torr. Residual gas analysis shows that most of the gas content is nitrogen (mass of N_2 is 2 x 14 = 28 AMU).
   a. [5 pts] Calculate the flux of N_2 on the substrate during RT evaporation.
   b. [5 pts] Calculate the flux of Si *from the crucible* held at 1500 K.

$$J = \frac{p}{\sqrt{2\pi m k_B T}} \qquad J = \frac{p_{\text{vap}}}{\sqrt{2\pi m_{\text{source}} k_B T_{\text{source}}}}$$

Vapor pressure of selected elements.
Dots correspond to melting points.



Answer: In both a) and b) the mass is 28 AMU x 1.66 x 10^{-27} kg/amu = 4.65 x 10^{-26} kg. a)
a) For the nitrogen flux, use *p* = 2 x 10-7 Torr and T = 293 K to get

J = 7.66 x 10^{17} N_2/m^2s.

b) For the Si flux, use the vapor pressure at *T* = 1500 K read from the chart provided, *p* = (10^{-5} Torr/760 Torr/atm) x 10^5 Pa/atm to get

J = 1.8 x 10^{19} Si//m^2s.