EECS 243 – Advanced IC Processing and Layout

Fall 2000 Office Hours Prof. A. R. Neureuther,
Tu, Th 3:30-5 M, Tu,Th, (F) 11am 510 Cory Hall, 2-4590
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Homework Assignment # 4, Due Th, Sept 28th, 00

Reading for Week#3: PDG 238-241, 256-271; ARNL1 138-150; The talk by Professor Grant Willson at the FEI seminar **www.fsi-intl.com/products/brkfst.html** has current information.

4.1 Thin-film effects in resists (Anyone for an HP calculator or a Smith chart?)

Consider a 248 nm resist with refractive index $n = 1.8 - j0.03$ about 500 nm thick on a silicon substrate with $n = 1.68 - j3.58$.

a) Find the reflection coefficient and reflectivity of the substrate without resist in air.
b) Find the reflection coefficient of the substrate seen in the resist.
c) Find the vertical contrast in the resist $\{C_V = (I_{max} - I_{min})/(I_{max} + I_{min})\}$.
d) Find the minimum reflectivity possible when the resist coating is present and the attenuation of the standing wave in the resist is ignored. (Hint: the resist helps reduce $n_{eq.\ sub}$ to n_{stack})
e) Find the reflectivity if the resist is hard baked at very high temperature such that $n = 1.8 - j0.2$ and the attenuation is so large that the reflection at the resist/silicon interface can be ignored.

4.2 Nonlinearity of resist dissolution rate with exposure

Assume the dissolution rate for an i-line (365 nm) positive resist is given by $R(E) = R_o(E/E_o)^n$ where E is the exposure dose in mJ/cm^2, E_o is the reference exposure dose of 30 mJ/cm^2, $R_o = 4$ nm/s and $n = 3$. Assume that the resist is 1.0 µm thick and the absorption constant α is 0.67 µm^{-1}. Ignore front surface reflections and substrate reflections so that the exposure has a simple exponential decay with depth from the initial value of the aerial image (image without the wafer present). A 1.0 µm dense (line-space) pattern is exposed in the resist using the NA of 0.3 i-line tool in the Microfabrication Lab. The exposure dose is 100 mJ/cm^2.

a) Estimate the development time required to first clear the brightest part of the above image.
b) Estimate the development time required to move horizontally along the substrate from the brightest location to the 0.3 intensity level at the line edge.
c) Estimate the time to develop vertically downward to the substrate at the location of the 0.3 intensity level and compare this to the sum of **a)** and **b)**. Comment on why it is larger.

4.3 Models for Chemically amplified resists

Use the rate constants in the differential equations for chemically-amplified resists on pp. 3341 of Croffie et al. JVST-B, 1999. Add a term $-k_l HB$ to the rate of change of acid to account for acid-base recombination and add a separate equation for the base decay rate $\delta B/\delta t = -k_l HB$. Assume the initial normalized values are $H = 0.10$ cm^{-3}, $B = 0.025$ cm^{-3}, $P = 1$ cm^{-3} and $k_l = 3$ µm^3/s.

a) How quickly do the volatile products decrease and free volume relax compared to the rte of deprotection?
b) If F rises to 0.2 for 1 second, what is the diffusion length sqrt (2Dt).
c) Use the 1D resist applet under LAVA applications to show that $\omega = 4$ and $D_o = 1 \times 10^{-4}$ µm-1/s cause the acid to sharpen where as $\omega = 0$ and $D_o = 1 \times 10^{-4}$ µm-1/s do not and that.
d) a threshold level of deprotection (such as 0.24 on the blue curve) advances with bake time at a more linear rate wit the default concentration dependent parameters than with the above Fickean diffusion.