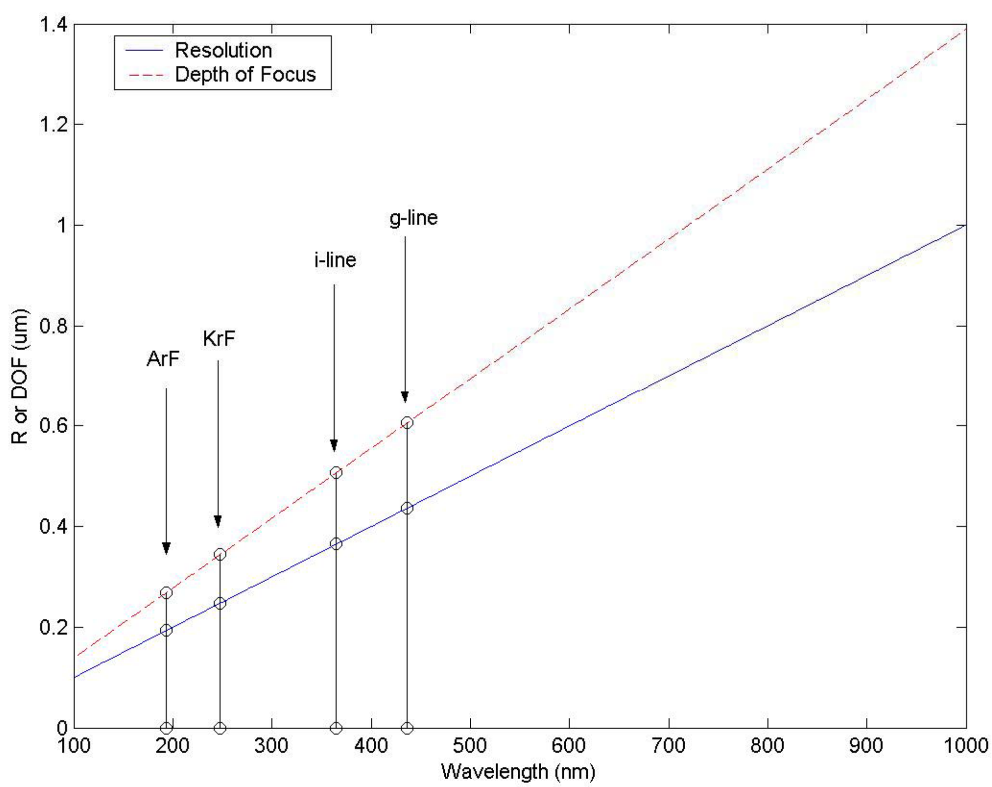
3.155/6.152J
Fall 2005
Homework # 6 – Solutions

1) From the notes and the reading, we know:

$$R = \frac{k_1 \lambda}{NA} \qquad \text{and} \qquad DOF = \frac{k_2 \lambda}{NA^2}$$

With $k_1 = 0.6$, $k_2 = 0.5$, and $NA = 0.6$, we obtain the plot below for wavelengths between 100nm and 1000nm. Common exposure wavelengths are ArF at 193nm, KrF at 248nm, i-line at 365nm, and g-line at 436nm.

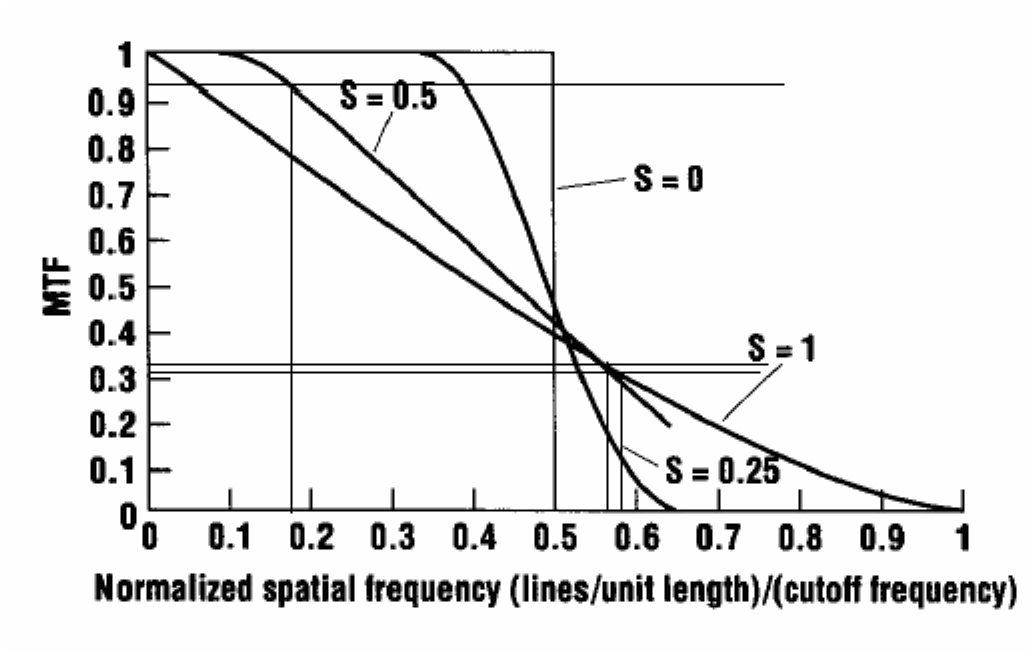
According to these calculations, the ArF source will not be adequate for the 0.13 and 0.1 micron IC technologies. The minimum resolution possible with an ArF source from these calculations is 0.193m microns. Despite these calculations, there are “tricks” that can be implemented so that an ArF source can be used. Such “tricks” include phase-shifting, modification of the spatial coherence of the exposure system, or using “wet” photolithography – where water or a liquid with a higher index of refraction than air is used to increase NA by being placed between the mask and the photoresist.



2) To calculate the CMTF, we use the equation specified in the reading which is:

$$CMTF = \frac{Q_f - Q_0}{Q_f + Q_0} = \frac{10^{1/\gamma} - 1}{10^{1/\gamma} + 1}$$

where γ is the contrast of the AZ-1450 resist for the given wavelength. For the given aligner and resist, a line can be transferred from a mask to the resist only when the MTF $\geq$ CMTF. The minimum line-width achievable is when MTF = CMTF. The ordinate of the given MTF plot is [1/(2W)]/[1/R] where W is the line-width and R is the value of the Rayleigh criteria. R is the theoretical resolution achievable for a given wavelength with $k_1 = 0.61$ (always for the Rayleigh criteria) and NA = 0.4 (for this given aligner system). The given MTF is for a mask with lines and spaces of width W so the spatial frequency is 1/(2W) while the cutoff frequency is 1/R.



From the given figure and the above equations, we have the following results:

Wavelength	Contrast	CMTF	R	f	W
248 nm	0.7	.928	378.2 nm	~0.18	1050.55 nm
313 nm	3.4	.326	477.3 nm	~0.56	426.18 nm
365 nm	3.6	.309	556.6 nm	~0.58	479.85 nm
436 nm	3.6	.309	664.9 nm	~0.58	573.19 nm