Modeling Dielectric Mixtures

MSE/EE 590 Discussion 11

Electromagnetic mixing formulas and applications

Ari Sihvola Chapter 8: Difficulties and uncertainties in classical mixing.

Analysis of the effective permittivity of inhomogeneous dielectrics formed by diblock-copolymer arrays

N. Bowler, Research note.

Lossy Inclusions

Look! ε'$_{eff}$ > ε'$_i$!!!

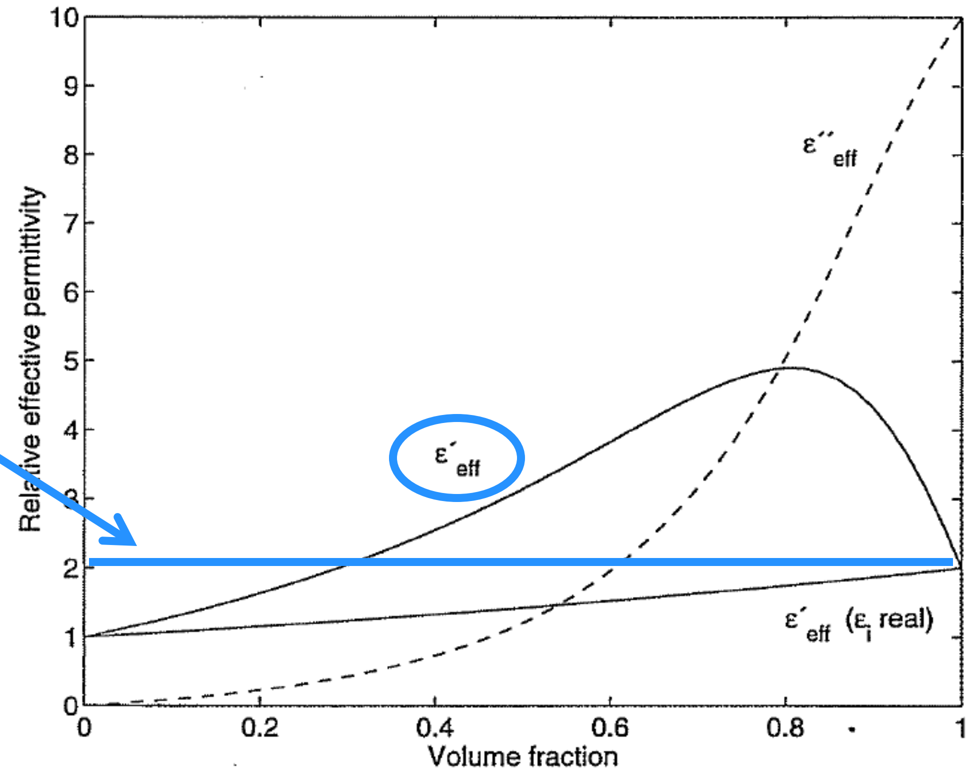


Figure 4.13: *The effective permittivity of a mixture with lossy inclusions. The permittivity of the inclusions relative to background is $\epsilon_i/\epsilon_e = 2 - j10$. The corresponding lossless case (inclusion permittivity $\epsilon_i/\epsilon_e = 2$) is completely different in character.*

Wiener Bounds for Real ε

$E_i = E_h$ because E_t is continuous. Therefore $D_i/D_h = \varepsilon_i/\varepsilon_h$.

$D_i = D_h$ because D_n is continuous. Therefore $E_i/E_h = \varepsilon_h/\varepsilon_i$.

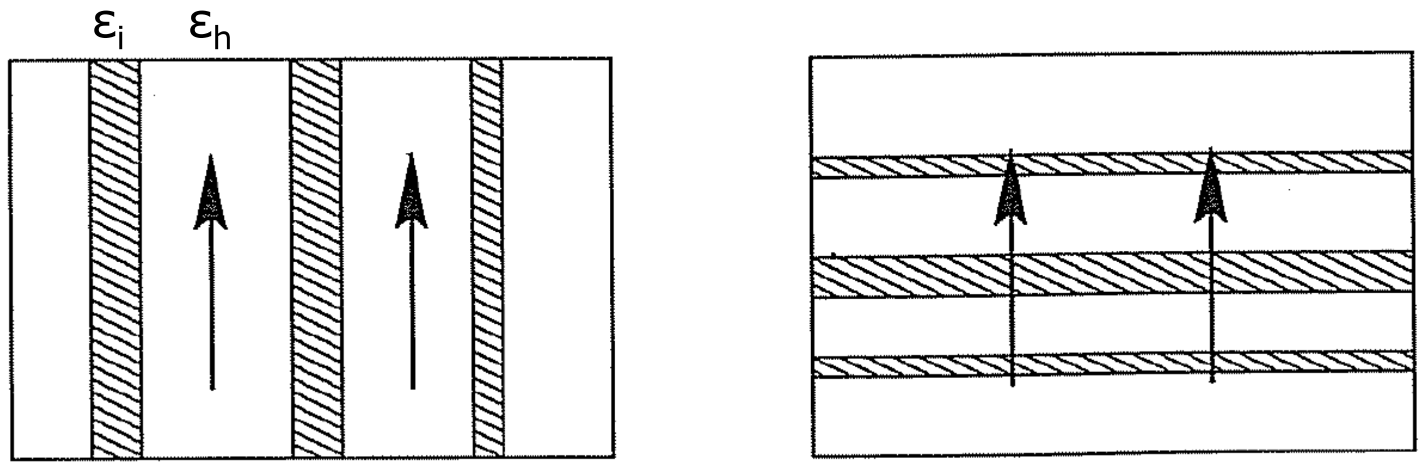


Figure 8.2: *The maximum effective permittivity or conductivity for a given volume fraction of inclusions comes if the inclusions are along the flux according to the left side. Likewise, the minimum effective corresponds to the right-hand side where the flux (flow) is forced to pass through the phase with lower permittivity (conductivity).*

Wiener Bounds for Complex ε

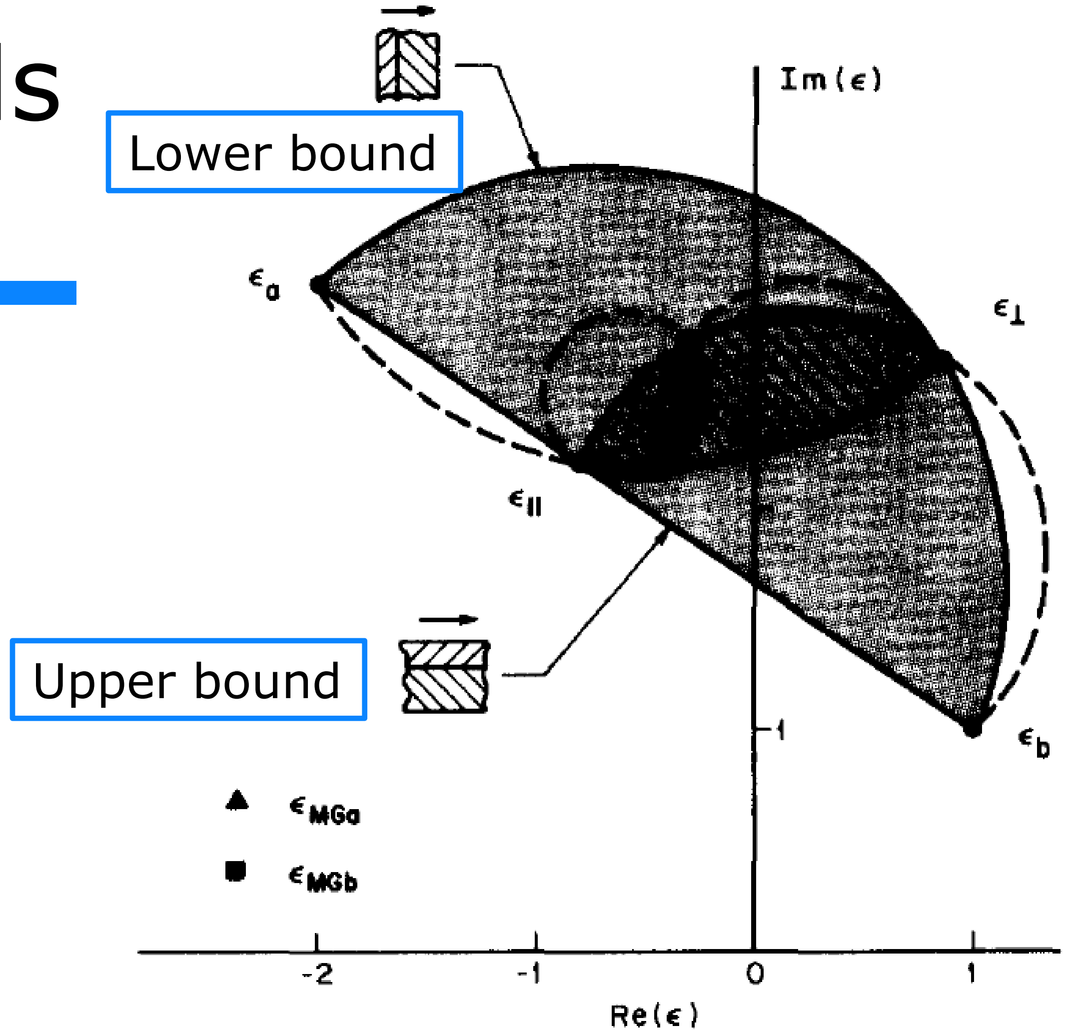
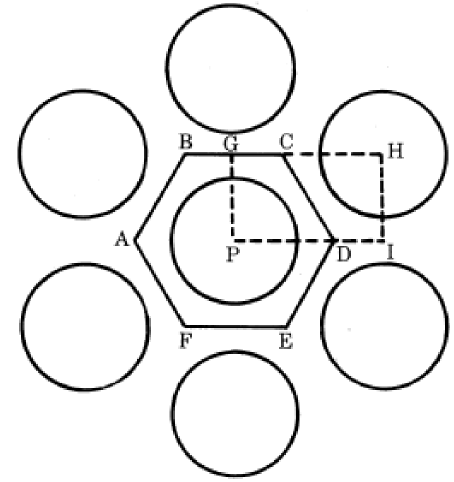


Fig. 5. Allowed values of ϵ for a two-component heterogeneous dielectric. The largest region defines the allowed range of ϵ if no information on composition or microstructure is available. The next region illustrates the allowed range if the composition (here 60% a, 40% b) is known. The smallest region applies if the composite is macroscopically isotropic (after Ref. 27).

D. E. Aspnes, *Am. J. Phys.*, 1982.

Hexagonal Array of Cylinders/Fibers



$f_{max} \approx 0.907$

TABLE 1. VALUES OF CONDUCTIVITY FOR THE HEXAGONAL ARRAY FOR VARIOUS VALUES OF THE CYLINDER CONDUCTIVITY (σ) AND VARIOUS VOLUME FRACTIONS (f)

	σ						
f	2	3.5	5	10	20	50	∞
0.1	1.0690	1.1176	1.1429	1.1782	1.1990	1.2126	1.2222
0.2	1.1429	1.2500	1.3077	1.3913	1.4419	1.4757	1.5000
0.3	1.2222	1.4000	1.5000	1.6506	1.7451	1.8100	1.8572
0.4	1.3077	1.5715	1.7274	1.9733	2.1348	2.2490	2.3340
0.5	1.4001	1.7696	2.0008	2.3865	2.6551	2.8530	3.0047
0.6	1.5002	2.0016	2.3368	2.9376	3.3901	3.7433	4.0267
0.65	1.5536	2.1336	2.5363	3.2906	3.8883	4.3738	4.7760
0.7	1.6095	2.2785	2.7631	3.7190	4.5252	5.2147	5.8111
0.73	1.6443	2.3727	2.9152	4.0245	5.0031	5.8733	6.6524
0.76	1.6800	2.4731	3.0818	4.3778	5.5830	6.7076	7.7600
0.78	1.7045	2.5439	3.2022	4.6467	6.0459	7.4036	8.7223
0.80	1.7295	2.6182	3.3311	4.9489	6.5907	8.2600	9.9586
0.82	1.7550	2.6962	3.4699	5.2924	7.2452	9.3479	11.6207
0.84	1.7810	2.7785	3.6202	5.6887	8.0536	10.7931	14.0093
0.85	1.7943	2.8213	3.7002	5.9117	8.5374	11.7200	15.6656
0.86	1.8077	2.8655	3.7840	6.1554	9.0930	12.8495	17.8381
0.87	1.8212	2.9110	3.8719	6.4237	9.7427	14.2733	20.8570
0.88	1.8349	2.9579	3.9645	6.7225	10.5216	16.1565	25.4508
0.89	1.8488	3.0064	4.0623	7.0606	11.4922	18.8532	33.7007
0.895	1.8558	3.0313	4.1136	7.2486	12.0856	20.7614	41.3407
0.90	1.8628	3.0568	4.1665	7.454	12.790	23.397	56.229

W. T. Perrins et al, *Proc. Roy. Soc. Lond. A*, 1979.