

Supplementary Material

SOURCE CODE:
MATLAB 2013 a

```
%effective permittivity of composites Fe3O4@Au+Hb CALCULATION
%=====
clc;clear;
x=0.8;
em=1.76;          % water (n=1.33)
ep1=1.790         % Hb (n=1.338)
ep2=0.778373+3.19889i %Fe3O4@Au
r0=5.0d-9;
R=20.0d-9;
alpha=(r0/R)^3;
p=2*ep1+ep2+2*alpha*(ep2-ep1);
q=2*ep1+ep2-alpha*(ep2-ep1);
ec=ep1*(p/q);
%----- abc formulation
a=2;
b=-((2*em)+(ec)-(x.*3*em)+(x.*ec));
c=-(em*ec);
d=sqrt(b.^2-4*a*c);

e_eff1=(b+(sqrt(b.^2-4*a*c)))/2*a;
e_eff2=(b-(sqrt(b.^2-4*a*c)))/2*a;

%ef1=-b/2*a;
%ef2=d/2*a;

n_eff1=sqrt(e_eff1);
n_eff2=sqrt(e_eff2);

ef1r=real(e_eff1);
ef1i=imag(e_eff1);

ef2r=real(e_eff2);
ef2i=imag(e_eff2);

ef1=e_eff1';
ef2=e_eff2';
nf1=n_eff1;
nf2=n_eff2;

sum (e_eff1)
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ATR SPECTRUM

%REFLECTIVITY SPECTRA

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lamda=633.0d-9;
pi=acos(-1.0d0);
p=sqrt(-1);
% ----- Prism BK7 633 nm -----
en(1)=1.51d0;
ek(1)=0.0d0;
n(1)=en(1)+ek(1)*p;
er(1)=en(1)^2-ek(1)^2;
ei(1)=2.0d0*en(1)*ek(1);
e(1)=er(1)+ei(1)*p;

% ----- Metal thin film(Ag) 633 nm -----
en(2)=0.13455d0;
ek(2)=3.98651d0;
n(2)=en(2)+ek(2)*p;
er(2)=en(2)^2-ek(2)^2;
ei(2)=2.0d0*en(2)*ek(2);
e(2)=er(2)+ei(2)*p;
% ----- Ag Thickness (meter) -----
d(2)=40.0d-9;

%----- Hb Layer-----
%e(3)=1.790+0.0*p;

d(3)= 20.0d-9;

%-----Fe3O4+Hb+Water
e(4)=2.1096+0.0166*p;
% ----- composites thickness -----
d(4)= 20.0d-9;

% ----- Fe3O4@Au+Hb+Water-----
e(5)=2.1010+0.0330*p;% 5 nm F=0.1 for (b/a=18/20=0.73)
%e(5)=2.18190+0.2627*p;% 10 nm F=0.1
%e(5)=2.3995+0.8702*p;% 15 nm F=0.1
%e(5)=2.7374+1.9570*p;%20 nm F=0.1 Eff1
%e(5)=4.6896-11.3446*p;%20 nm F=0.1 Eff2
%=====
%e(5)=3.026+1.4341*p;% 20 nm F=0.1 for (b/a=19/20)
%e(5)=2.7374+1.9570*p;% 20 nm F=0.1 for (b/a=18/20)
%e(5)=2.5443+2.683*p;% 20 nm F=0.1 (17/20)
%e(5)=2.5751+3.5545*p;% 20 nm F=0.1 (16/20)
%e(5)=3.3631+5.1915*p;% 20 nm F=0.1 (14/20)
%e(5)=5.3701+6.8311*p;% 20 nm F=0.1 (10/20)

%e(5)=3.50126+0.364153*p;% 20 nm F=0.8 for (b/a=19/20)
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%e(5)=3.5236+0.5287*p;% 20 nm F=0.8 for (b/a=18/20)
%e(5)=3.6516+0.7152*p;% 20 nm F=0.8 (17/20)
%e(5)=3.9027+0.8216*p;% 20 nm F=0.8 (16/20)
%e(5)=11.9377-10.7030*p;% 20 nm F=0.8 (14/20)
%e(5)=23.3121-7.5564*p;% 20 nm F=0.8 (10/20)

%ep2=2.040082+3.193385i          %(20/19)
%ep2=0.778373+3.19889i          %Fe3O4@Au (20/18)
%ep2=-0.49070+3.161178i         %(20/17)
%ep2=-1.7455+3.081151i          %(20/16)
%ep2=-4.1333+2.81043i           %(20/14)
%ep2=-7.2926+2.0516i            %(20/10)

%=====
%e(5)=3.1000+0.0128*p;% 5 nm F=0.8
%e(5)=3.136112+0.09826*p;% 10 nm F=0.8
%e(5)=3.2598+0.2912*p;% 15 nm F=0.8
%e(5)=3.5236+0.5287*p;%20 nm F=0.8

% ----- layer 6 the air -----
en(6)=1.0d0;
ek(6)=0.0d0;
n(6)=en(6)+ek(6)*p;
er(6)=en(6)^2-ek(6)^2;
ei(6)=2.0d0*en(6)*ek(6);
e(6)=er(6)+ei(6)*p;

% ----- Scan initial angle -----
ang0=35.0d0;
ang1=60.0d0;

disp(' ');
disp('-----');
disp('initial angle | Reflectivity 3 | Reflectivity 4' );
disp('-----');
for i=1:301
    theta=(ang0+(i-1)/300.0d0*(ang1-ang0))/180.0d0*pi;
    theta_pi=theta/pi*180.0d0;
% ----- Reflectivity -----
    for j=1:6
        kz(j)=((2.0d0*pi)/lamda))*sqrt(e(j)-e(1)*sin(theta)^2);
    end
    r12=((kz(1)/e(1))-(kz(2)/e(2)))/((kz(1)/e(1))+(kz(2)/e(2)));
    r23=((kz(2)/e(2))-(kz(3)/e(3)))/((kz(2)/e(2))+(kz(3)/e(3)));
    r24=((kz(2)/e(2))-(kz(4)/e(4)))/((kz(2)/e(2))+(kz(4)/e(4)));
    r25=((kz(2)/e(2))-(kz(5)/e(5)))/((kz(2)/e(2))+(kz(5)/e(5)));
    r26=((kz(2)/e(2))-(kz(6)/e(6)))/((kz(2)/e(2))+(kz(6)/e(6)));
    r36=((kz(3)/e(3))-(kz(6)/e(6)))/((kz(3)/e(3))+(kz(6)/e(6)));
    r46=((kz(4)/e(4))-(kz(6)/e(6)))/((kz(4)/e(4))+(kz(6)/e(6)));
    r56=((kz(5)/e(5))-(kz(6)/e(6)))/((kz(5)/e(5))+(kz(6)/e(6)));

r236=(r23+(r36*exp(p*2.0d0*kz(3)*d(3))))/(1+(r23*r36*exp(p*2.0d0*kz(3)*d(3))
);

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r246=(r24+(r46*exp(p*2.0d0*kz(4)*d(4))))/(1+(r24*r46*exp(p*2.0d0*kz(4)*d(4)))
);

r256=(r25+(r56*exp(p*2.0d0*kz(5)*d(5))))/(1+(r25*r56*exp(p*2.0d0*kz(5)*d(5)))
);
% ----- Reflectivity three Layer P/Ag/Air-----

r1=((r12+(r26*exp(p*2.0d0*kz(2)*d(2))))/(1+(r12*r26*exp(p*2.0d0*kz(2)*d(2))))
);
r1c=conj(r1);
refl=r1*r1c;
%-----P/Ag/Hb/Air-----

r2=((r12+(r236*exp(p*2.0d0*kz(2)*d(2))))/(1+(r12*r236*exp(p*2.0d0*kz(2)*d(2)))
));
r2c=conj(r2);
ref2=r2*r2c;
%-----P/Ag/Fe3O4+Hb+Air-----

r3=((r12+(r246*exp(p*2.0d0*kz(2)*d(2))))/(1+(r12*r246*exp(p*2.0d0*kz(2)*d(2)))
));
r3c=conj(r3);
ref3=r3*r3c;

%-----P/Ag/Fe3O4@Au+Hb+Water/Air

r4=((r12+(r256*exp(p*2.0d0*kz(2)*d(2))))/(1+(r12*r256*exp(p*2.0d0*kz(2)*d(2)))
));
r4c=conj(r4);
ref4=r4*r4c;

fprintf('%10.2f | %10.5f | %10.5f \n',theta_pi,ref2,ref3,ref4);
fprintf('%10.2f \n',ref4);

plot(theta_pi,ref2,'.b',theta_pi,ref3,'.g',theta_pi,ref4,'.k');
plot(theta_pi,ref2,'.b',theta_pi,ref4,'.c');
plot(theta_pi,ref2,'.k',theta_pi,ref4,'k--','LineWidth',24);
plot(theta_pi,ref2,'.k',theta_pi,ref4,'k--*','linewidth',0.1);
plot(theta_pi,ref2,'.b');
plot(theta_pi,ref4,'.g');
plot(theta_pi,ref4,'--ko','linewidth',1);
hold on;
xlim([40 52]);
ylim([0 1]);
grid on;
set(gca,'color',[.9 0 0.8],'fontname','arial');
title('ATR Spectra','color',[0 .1 1],...
'fontweight','bold','fontsize',14);
xlabel('angle (DEG)','color',[0 .2 .2],...
'fontweight','bold','fontsize',9);
ylabel('REFLECTivity','color',[0 .2 .2],...
'fontweight','bold','fontsize',9);

end

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