In[1]:=
```
Print[];
Print["Metamaterial(SemiconductorsV52p1886).nb"];

Print[" ----------------------------------------------------"];
Print[" The Image of the Metamaterial of the paper  "];
Print[" Model of Metamaterial Based on Graphene Scrolls "];
Print[" and Carbon Nanotubes with Negative Refractive Index "];
Print[" / A.I. Siahlo, N.A. Poklonski, S.A. Vyrko and S.V. Ratkevich "];
Print[" //Semiconductors.– 2018.– V. 52,
    „ 14.– P.1886 (4 pp.). [DOI: 10.1134/S1063782618140294] "];
Print[" ----------------------------------------------------"];

Print[" I.1. The Input Parameters --------------"];
NumberScrollLayersp1 = 1; NumberScrollLayersp2 = 2;
NumberScrollLayersp = NumberScrollLayersp2;
Print["NumberScrollLayers=", NumberScrollLayersp];
n10 = 10; nNanotubep = n10;
Print["nNanotube=", nNanotubep];
nNanotubes2 = 2; nNanotubes3 = 3; nNanotubes4 = 4;
nScrolls2 = 2; nScrolls3 = 3; nScrolls31 = 3; nScrolls4 = 4;
nNanoscrollsXp = nScrolls3;
nNanoscrollsZp = nScrolls2;
nNanotubesYp = nNanotubes3;
nNanotubesZp = nNanotubes3;
Print["Along X-direction: nNanoscrollsX=", nNanoscrollsXp,
  ",  Along Z-direction: nNanoscrollsZ=", nNanoscrollsZp];
Print["Along Y-direction: nNanotubesY=", nNanotubesYp,
  ",  Along Z-direction: nNanotubesZ=", nNanotubesZp];
PhiRotPid2 = Pi / 2;
L12d7nm = 12.709 nm;
RIn1d1nm = 1.1 nm;
L15nm = 15. nm; L1p = L15nm;
L1p = L15nm;
L1p = L12d7nm;
Spirale1RotAnglep = 0;
Spirale2RotAnglep = Pi;
NanoribbonLengthp = L1p;
Print[" The length of a carbon nanoribbons L1=", L1p / nm, "nm"];
RIn1p = RIn1d1nm;
Print["The Inner radius of nanoscrolls RIn1=", RIn1p / nm, "nm"];
Lw1nm = 1 nm; Lw12nm = 12. nm;
Lw12nm = 12 nm; Lw60nm = 60 nm; Lw5nm = 5 nm;
Lwp = Lw5nm;
NanoscrollWidth = Lwp;
NanoribbonWidth = Lwp;
Print[" The carbon nanoscroll width w=", Lwp / nm, "nm"];
ShiftX0nm = 0 nm; ShiftY0nm = 0 nm;
Print[" I.5.The parameters for the visualisation"];
Nu10 = 40; Scale09 = 0.99;
ShowScrollSpirales = True;
ShowNanoscrollSingle = True;
ShowStructureProjections = True;
Print[" --------End Of The Input---------------"];

Print[" ----------------------------------------------------"];
ThisNotebookFileName = NotebookInformation[][[1, 2, 2]];
Print["ThisNotebookFileName = ", ThisNotebookFileName];
```

```
Print["I.0.1 The Units (nm, meV, AA)"];
"nm=10^(-9)m;";
nm = 10^(-9) m;
AA = 10^(-10) m;
JJkgms = kg m^2/s^2;
Farad = Amper^2 s^4 kg^(-1) m^(-2);
Cl = Amper s;
Volt = m^2 kg/s^3/Amper;
"eV=JJ Electronp;";
JJ = eV/Electron;
meV = N[eV/1000];
Print["I.0.2. The physical constants"];
Print[" The interatomic distance aCC and the interlayer distance h"];
aCC142AA = 1.42 AA; aCCp = aCC142AA;
NatomsInCell2 = 2; NatomsInCellp = NatomsInCell2;
Print["NatomsInCell=", NatomsInCellp];
h335nm = 0.3354 nm; hp = h335nm;
Print["aCC=", aCCp/nm, "nm, h=", hp/nm, " nm"];
Print["I.0.3. The functions that will be used"];
frNanotubenn[n_, aCC_] := n 3 aCC/(2 Pi);
fSpiraleLen[NumberScrollLayersv_, PhiInv_, PhiOutv_, hv_] :=
(1/(4 Pi) hv NumberScrollLayersv (-PhiInv Sqrt[1 + PhiInv^2] +
   PhiOutv Sqrt[1 + PhiOutv^2] - ArcSinh[PhiInv] +
   ArcSinh[PhiOutv]));
Print["fSpiraleLen[NumberScrollLayersv,PhiInv, PhiOutv, hv]=",
  fSpiraleLen[NumberScrollLayersv, PhiInv, PhiOutv, hv]];
fPhiOutvsPhiInLh[NumberScrollLayersv_, PhiInv_, Lv_, hv_] :=
 Sqrt[4 π Lv/(NumberScrollLayersv hv) + PhiInv^2];
Print["fPhiOutvsPhiInLh[NumberScrollLayersv,PhiInv, Lv, hv]=",
  fPhiOutvsPhiInLh[NumberScrollLayersv, PhiInv, Lv, hv]];
fPhivsRh[NumberScrollLayersv_, Rv_, hv_] := Rv 2 Pi/(NumberScrollLayersv hv);
Print["fPhivsRh[NumberScrollLayersv, Rv, hv]=", fPhivsRh[NumberScrollLayersv, Rv, hv] ];
fRvsPhih[NumberScrollLayersv_, Phiv_, hv_] := (NumberScrollLayersv hv) Phiv/(2 Pi);
Print["fRvsPhih[NumberScrollLayersv,Phiv,hv]=",
  fRvsPhih[NumberScrollLayersv, Phiv, hv] ];
fPhiOut1vsL1RIn1h[NumberScrollLayersv_, L1v_, RIn1v_, hv_] :=
 fPhiOutvsPhiInLh[NumberScrollLayersv,
   fPhivsRh[NumberScrollLayersv, RIn1v, hv], L1v, hv];
Print["fPhiOut1vsL1RIn1h[NumberScrollLayersv, L1v, RIn1v, hv]=",
  fPhiOut1vsL1RIn1h[NumberScrollLayersv, L1v, RIn1v, hv] ];
fPhiIn2[NumberScrollLayersv_, RIn1v_, hv_, dPhi12v_] :=
 fPhivsRh[NumberScrollLayersv, RIn1v, hv] + dPhi12v;
Print["fPhiIn2[NumberScrollLayersv, RIn1v, hv, dPhi12v]=",
  fPhiIn2[NumberScrollLayersv, RIn1v, hv, dPhi12v] ];
fPhiOut2[NumberScrollLayersv_, L1v_, RIn1v_, hv_, dPhi12v_] :=
 fPhiOutvsPhiInLh[NumberScrollLayersv,
   fPhiIn2[NumberScrollLayersv, RIn1v, hv, dPhi12v], L1v, hv];
rNanotubep = frNanotubenn[n10, aCCp];
rNanotubep = rNanotubep;
Print["rNanotube(", n, "," n, ")=", rNanotubep/nm, "nm"];
PhiIn1p = fPhivsRh[NumberScrollLayersp, RIn1p, hp];
PhiOut1p = fPhiOut1vsL1RIn1h[NumberScrollLayersp, L1p, RIn1p, hp];
Print["PhiIn1=", PhiIn1p/(2 Pi), "(2Pi), PhiOut1=",  PhiOut1p/(2 Pi), "(2Pi)"];
PhiIn2p = PhiIn1p + Pi;
PhiOut2p = PhiOut1p + Pi;
Print["PhiIn2=", PhiIn2p/(2 Pi), "(2Pi), PhiOut2=",  PhiOut2p/(2 Pi), "(2Pi)"];
ROut1p = fRvsPhih[NumberScrollLayersp, PhiOut1p, hp] ;
```

```
Print["RIn1=", RIn1p/nm, "nm,  ROut1=", ROut1p/nm, "nm"];
aScrollXZp = 2 ROut1p + hp + 2 rNanotubep;
Print[
  " The distance between the centrums of the NanoScrolls in the XZ-plane aScrollXZ=",
  aScrollXZp/nm, "nm"];
aNanotubesXYp = 2 ROut1p + hp + 2 rNanotubep;
Print[
  " The distance between the centrums of the Nanotubes in the XY-plane aNanotubesXY=",
  aNanotubesXYp/nm, "nm"];
NanotubeLengthXp = aScrollXZp (nNanoscrollsXp + 1);
Print["The Length of the Nanotubes along the X-axe: NanotubeLengthX=",
  NanotubeLengthXp/nm, "nm"];
NanoscrollLengthYp = aNanotubesXYp (nNanotubesZp);
Print["The Length of the Nanoscrolls along the Y-axe: NanoscrollLengthY=",
  NanoscrollLengthYp/nm, "nm"];
StructureLengthZp = nNanotubesZp aScrollXZp;
Print["The Length of the Structure along the Z-axe: StructureLengthZ=",
  StructureLengthZp/nm, "nm"];

nm = 1.; m = 10^9 nm;

Print["Draw the spirales of a nanoscroll"];
Spirale1ScrollSingle = ParametricPlot[
   {Cos[Phiv] (Phiv - Spirale1RotAnglep) (NumberScrollLayersp hp) / (2 Pi) / nm Scale09,
    Sin[Phiv] (Phiv - Spirale1RotAnglep) (NumberScrollLayersp hp) / (2 Pi) / nm Scale09},
   {Phiv, Spirale1RotAnglep + PhiIn1p, Spirale1RotAnglep + PhiOut1p},
   PlotRange -> {{-ROut1p/nm, ROut1p/nm }, {-ROut1p/nm, ROut1p/nm }},
   PlotStyle -> {Black, Thick}, Axes -> True];

If[NumberScrollLayersp == 1,
If[ShowScrollSpirales,
Print["Show[Spirale1ScrollSingle]:"];
Print[Show[Spirale1ScrollSingle]];
];
];
Spirale2ScrollSingle = ParametricPlot[
   {Cos[Phiv] (Phiv - Spirale2RotAnglep) (NumberScrollLayersp hp) / (2 Pi) / nm Scale09,
    Sin[Phiv] (Phiv - Spirale2RotAnglep) (NumberScrollLayersp hp) / (2 Pi) / nm Scale09},
   {Phiv, Spirale2RotAnglep + PhiIn2p - Pi, Spirale2RotAnglep + PhiOut2p - Pi},
   PlotRange -> {{-ROut1p/nm, ROut1p/nm }, {-ROut1p/nm, ROut1p/nm }},
   PlotStyle -> {Gray, Thick}, Axes -> True];
If[NumberScrollLayersp == 2,
If[ShowScrollSpirales,
Print["Show[{Spirale1ScrollSingle,Spirale2ScrollSingle}]:"];
Print[Show[{Spirale1ScrollSingle, Spirale2ScrollSingle}]];];
];
Print[];
Print["Draw the spirales of the nanoscrolls of the structure:"];
Print["aScrollXZp=", aScrollXZp/nm, "nm"];
Print["aScrollXZp=2ROut1p+hp+2rNanotubep,  {2ROut1p,hp,2rNanotubep}=",
  {2 ROut1p, hp, 2 rNanotubep}];
tSpirale1Scroll = Table[ParametricPlot[
    {aScrollXZp (iScrollX - nNanoscrollsXp) + Cos[Phiv] (Phiv - Spirale1RotAnglep)
       (NumberScrollLayersp hp) / (2 Pi) Scale09, aScrollXZp (jScrollY - nNanoscrollsZp) +
      Sin[Phiv] (Phiv - Spirale1RotAnglep) (NumberScrollLayersp hp) / (2 Pi) Scale09},
    {Phiv, Spirale1RotAnglep + PhiIn1p, Spirale1RotAnglep + PhiOut1p},
    PlotRange -> {{-(nNanoscrollsXp - 1) aScrollXZp - 1 ROut1p, ROut1p },
```

```
      {-(nNanoscrollsZp - 1) aScrollXZp - 1 ROut1p, ROut1p }}, PlotStyle -> {Black, Thick},
    Axes -> True], {iScrollX, 1, nNanoscrollsXp}, {jScrollY, 1, nNanoscrollsZp}];
If[ShowScrollSpirales,
Print["Show[tSpirale1Scroll]:"];
Print[Show[tSpirale1Scroll, ImageSize -> Large]];
];
tSpirale2Scroll = Table[ParametricPlot[
    {aScrollXZp (iScrollX - nNanoscrollsXp) + Cos[Phiv] (Phiv - Spirale2RotAnglep)
       (NumberScrollLayersp hp) / (2 Pi) Scale09, aScrollXZp (jScrollY - nNanoscrollsZp) +
      Sin[Phiv] (Phiv - Spirale2RotAnglep) (NumberScrollLayersp hp) / (2 Pi) Scale09},
    {Phiv, Spirale2RotAnglep + PhiIn2p - Pi, Spirale2RotAnglep + PhiOut2p - Pi},
    PlotRange -> {{-(nNanoscrollsXp - 1) aScrollXZp - 1 ROut1p, ROut1p },
      {-(nNanoscrollsZp - 1) aScrollXZp - 1 ROut1p, ROut1p }}, PlotStyle -> {Gray, Thick},
    Axes -> True], {iScrollX, 1, nNanoscrollsXp}, {jScrollY, 1, nNanoscrollsZp}];
If[ShowScrollSpirales,
If[NumberScrollLayersp == 1,
Print["Show[tSpirale1Scroll]:"]; Print[Show[tSpirale1Scroll, ImageSize -> Large]];
];
If[NumberScrollLayersp == 2,
Print["Show[tSpirale1Scroll,tSpirale2Scroll]:"];
   Print[Show[tSpirale1Scroll, tSpirale2Scroll, ImageSize -> Large]];
];
];
Print["Draw the Nanotubes of the structure:"];
nm = 1; m = 10^9 nm; N07 = 0.7;
tNanotubeYZ =
  Table[ParametricPlot3D[{xv, jNanotubeY aScrollXZp - aScrollXZp 0.5 + Cos[Phiv] rNanotubep,
     (kNanotubeZ - 1) aScrollXZp + Sin[Phiv] rNanotubep},
    {Phiv, Spirale1RotAnglep + PhiIn1p, Spirale1RotAnglep + PhiOut1p},
    {xv, aScrollXZp 0.45, NanotubeLengthXp - aScrollXZp 0.55},
    PlotPoints -> 5, PlotStyle -> {Gray, Thick},
    PlotRange -> {{-aScrollXZp N07, NanotubeLengthXp + aScrollXZp N07},
      {-aNanotubesXYp N07, NanoscrollLengthYp + aNanotubesXYp N07},
      {-aScrollXZp N07, (nNanoscrollsZp) aScrollXZp + aScrollXZp N07}}, (*Axes->None,*)
    ColorFunction -> Function[{x, y, z, u, v}, Gray], ColorFunctionScaling -> False],
   {jNanotubeY, 1, nNanotubesYp}, {kNanotubeZ, 1, nNanotubesZp}];
(*Print["The tNanotubeYZ:"];
Print[Show[tNanotubeYZ,ViewPoint->Front]];*)
nm = 1.; m = 10^9 nm; N01 = 0.01;
Print["Define all 3D-scrolls"];
Scroll13D00 =
  ParametricPlot3D[{Cos[Phiv] (Phiv - Spirale1RotAnglep) NumberScrollLayersp hp / (2 Pi),
    yv, Sin[Phiv] (Phiv - Spirale1RotAnglep) NumberScrollLayersp hp / (2 Pi)},
   {Phiv, Spirale1RotAnglep + PhiIn1p, Spirale1RotAnglep + PhiOut1p},
   {yv, 0, NanoscrollLengthYp}, PlotPoints -> 5,
   PlotStyle -> {Gray, Thick}, PlotRange -> {{-ROut1p / nm, ROut1p / nm},
     {-aScrollXZp N07, NanoscrollLengthYp / nm}, {-ROut1p / nm, ROut1p / nm}}, Axes -> True,
   ColorFunction -> Function[{x, y, z, u, v}, Gray], ColorFunctionScaling -> False];
Scroll23D00 = ParametricPlot3D[{Cos[Phiv] (Phiv - Spirale2RotAnglep) NumberScrollLayersp
     hp / (2 Pi), yv, Sin[Phiv] (Phiv - Spirale2RotAnglep) NumberScrollLayersp hp / (2 Pi)},
   {Phiv, Spirale2RotAnglep + PhiIn2p - Pi, Spirale2RotAnglep + PhiOut2p - Pi},
   {yv, 0, NanoscrollLengthYp}, PlotPoints -> 5,
   PlotStyle -> {Gray, Thick}, PlotRange -> {{-ROut1p / nm, ROut1p / nm},
     {-aScrollXZp N07, NanoscrollLengthYp / nm}, {-ROut1p / nm, ROut1p / nm}}, Axes -> True,
   ColorFunction -> Function[{x, y, z, u, v}, LightGray], ColorFunctionScaling -> False];
If[NumberScrollLayersp == 1,
If[ShowNanoscrollSingle,
```

```
Print["Show[Scroll13D00]:"];
Print[Show[Scroll13D00, ImageSize -> Small]];
];
];
If[NumberScrollLayersp == 2,
If[ShowNanoscrollSingle,
Print["Show[Scroll13D00],
       Show[Scroll23D00],                    Show[Scroll13D00,Scroll23D00]:"];
Print[Show[Scroll13D00, ImageSize -> Small], Show[Scroll23D00, ImageSize -> Small],
     "              ", Show[Scroll13D00, Scroll23D00, ImageSize -> Small]];
];
];

Print["Define tScroll13DXZ and tScrol23DXZ"];
tScroll13DXZ = Table[ParametricPlot3D[
    {iNanoscrollX aScrollXZp / nm + Cos[Phiv] (Phiv - Spirale1RotAnglep) NumberScrollLayersp
       hp / nm / (2 Pi), yv, -aScrollXZp / nm / 2 + kNanoscrollZ aScrollXZp / nm +
      Sin[Phiv] (Phiv - Spirale1RotAnglep) NumberScrollLayersp hp / nm / (2 Pi)},
    {Phiv, Spirale1RotAnglep + PhiIn1p, Spirale1RotAnglep + PhiOut1p},
    {yv, 0, NanoscrollLengthYp}, PlotPoints -> 5, PlotStyle -> {Gray, Thick},
    PlotRange -> {{-aScrollXZp N07, NanotubeLengthXp + aScrollXZp N07},
      {-aNanotubesXYp N07, NanoscrollLengthYp + aNanotubesXYp N07},
      {-aScrollXZp N07, (nNanoscrollsZp) aScrollXZp + aScrollXZp N07}}, Axes -> True,
    ColorFunction -> Function[{x, y, z, u, v}, Gray], ColorFunctionScaling -> False],
   {iNanoscrollX, 1, nNanoscrollsXp}, {kNanoscrollZ, 1, nNanoscrollsZp}];
tScroll23DXZ = Table[ParametricPlot3D[{iNanoscrollX aScrollXZp / nm +
      Cos[Phiv] (Phiv - Spirale2RotAnglep) NumberScrollLayersp hp / nm / (2 Pi),
     yv, -aScrollXZp / nm / 2 + kNanoscrollZ aScrollXZp / nm +
      Sin[Phiv] (Phiv - Spirale2RotAnglep) NumberScrollLayersp hp / nm / (2 Pi)},
    {Phiv, Spirale2RotAnglep + PhiIn2p - Pi, Spirale2RotAnglep + PhiOut2p - Pi},
    {yv, 0, NanoscrollLengthYp}, PlotPoints -> 5, PlotStyle -> {Gray, Thick},
    PlotRange -> {{-aScrollXZp N07, NanotubeLengthXp + aScrollXZp N07},
      {-aNanotubesXYp N07, NanoscrollLengthYp + aNanotubesXYp N07},
      {-aScrollXZp N07, (nNanoscrollsZp) aScrollXZp + aScrollXZp N07}}, Axes -> True,
    ColorFunction -> Function[{x, y, z, u, v}, LightGray], ColorFunctionScaling -> False],
   {iNanoscrollX, 1, nNanoscrollsXp}, {kNanoscrollZ, 1, nNanoscrollsZp}];
(*Print["Show[tScroll13DXZ,tScroll23DXZ]:"];
Print[Show[tScroll13DXZ,tScroll23DXZ,ImageSize->Medium]];*)
Print["    --------Show the Metamaterial:-----------"];
Print["    (Fig.4 of the paper"];
Print["     Model of Metamaterial Based on Graphene Scrolls "];
Print["     and Carbon Nanotubes with Negative Refractive Index "];
Print["     / A.I. Siahlo, N.A. Poklonski, S.A. Vyrko and S.V. Ratkevich "];
Print["     //Semiconductors.— 2018.— V. 52, „ 14.— P.1886 (4 pp.).   ) "];
Print[Show[tScroll13DXZ, tScroll23DXZ, tNanotubeYZ, ImageSize -> Medium,
   ViewPoint -> {StructureLengthZp 1000, StructureLengthZp 1000
, StructureLengthZp 1000}]];
If[ShowStructureProjections,
  Print["   and its projections:"];
  Print[
   Show[tScroll13DXZ, tScroll23DXZ, tNanotubeYZ, ImageSize -> Medium, ViewPoint -> Front],
   Show[tScroll13DXZ, tScroll23DXZ, tNanotubeYZ, ImageSize -> Medium, ViewPoint -> Left]];
Print[Show[tScroll13DXZ, tScroll23DXZ, tNanotubeYZ, ImageSize -> Medium, ViewPoint -> Top]];
];
Print["The parameters of the metamaterial"];
Print["      {nNanoscrollsXp,nNanotubesYp,nNanoscrollsZp,nNanotubesZp}:"];
Print["      ", {nNanoscrollsXp, nNanotubesYp, nNanoscrollsZp, nNanotubesZp}];
```

Metamaterial(SemiconductorsV52p1886).nb

The Image of the Metamaterial of the paper

Model of Metamaterial Based on Graphene Scrolls

and Carbon Nanotubes with Negative Refractive Index

/ A.I. Siahlo, N.A. Poklonski, S.A. Vyrko and S.V. Ratkevich

//Semiconductors.— 2018.— V. 52, „ 14.— P.1886 (4 pp.). [DOI: 10.1134/S1063782618140294]

I.1. The Input Parameters ----------

NumberScrollLayers=2

nNanotube=10

Along X-direction: nNanoscrollsX=3, Along Z-direction: nNanoscrollsZ=2

Along Y-direction: nNanotubesY=3, Along Z-direction: nNanotubesZ=3

The length of a carbon nanoribbons L1=12.709nm

The Inner radius of nanoscrolls RIn1=1.1nm

The carbon nanoscroll width w=5nm

I.5.The parameters for the visualisation

--------End Of The Input----------

ThisNotebookFileName = Metamaterial(SemiconductorsV52p1886).m

I.0.1 The Units (nm, meV, AA)

I.0.2. The physical constants

The interatomic distance aCC and the interlayer distance h

NatomsInCell=2

aCC=0.142nm, h=0.3354 nm

I.0.3. The functions that will be used

$$\text{fSpiraleLen}[\text{NumberScrollLayersv},\text{PhiInv},\ \text{PhiOutv},\ \text{hv}] = \frac{1}{4\pi}\text{hv}\,\text{NumberScrollLayersv}\left(-\text{PhiInv}\sqrt{1+\text{PhiInv}^2}+\text{PhiOutv}\sqrt{1+\text{PhiOutv}^2}-\text{ArcSinh}[\text{PhiInv}]+\text{ArcSinh}[\text{PhiOutv}]\right)$$

$$\text{fPhiOutvsPhiInLh}[\text{NumberScrollLayersv},\text{PhiInv},\ \text{Lv},\ \text{hv}] = \sqrt{\text{PhiInv}^2+\frac{4\,\text{Lv}\,\pi}{\text{hv}\,\text{NumberScrollLayersv}}}$$

$$\text{fPhivsRh}[\text{NumberScrollLayersv},\ \text{Rv},\ \text{hv}] = \frac{2\,\pi\,\text{Rv}}{\text{hv}\,\text{NumberScrollLayersv}}$$

$$\text{fRvsPhih}[\text{NumberScrollLayersv},\text{Phiv},\text{hv}] = \frac{\text{hv}\,\text{NumberScrollLayersv}\,\text{Phiv}}{2\,\pi}$$

fPhiOut1vsL1RIn1h[NumberScrollLayersv, L1v, RIn1v, hv]=

$$\sqrt{\frac{4\,L1v\,\pi}{hv\,NumberScrollLayersv}+\frac{4\,\pi^2\,RIn1v^2}{hv^2\,NumberScrollLayersv^2}}$$

fPhiIn2[NumberScrollLayersv, RIn1v, hv, dPhi12v]=dPhi12v+$\frac{2\,\pi\,RIn1v}{hv\,NumberScrollLayersv}$

rNanotube(n, n)=0.678nm

PhiIn1=1.63983(2Pi), PhiOut1=2.95292(2Pi)

PhiIn2=2.13983(2Pi), PhiOut2=3.45292(2Pi)

RIn1=1.1nm, ROut1=1.98082nm

The distance between the centrums of the NanoScrolls in the XZ-plane aScrollXZ=5.65304nm

The distance between the centrums of the Nanotubes in the XY-plane aNanotubesXY=5.65304nm

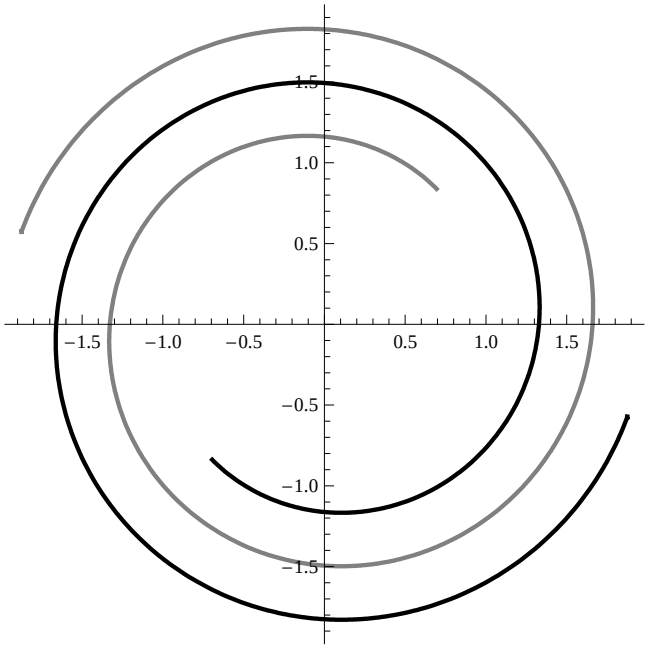
The Length of the Nanotubes along the X-axe: NanotubeLengthX=22.6122nm

The Length of the Nanoscrolls along the Y-axe: NanoscrollLengthY=16.9591nm

The Length of the Structure along the Z-axe: StructureLengthZ=16.9591nm

Draw the spirales of a nanoscroll

Show[{Spirale1ScrollSingle,Spirale2ScrollSingle}]:

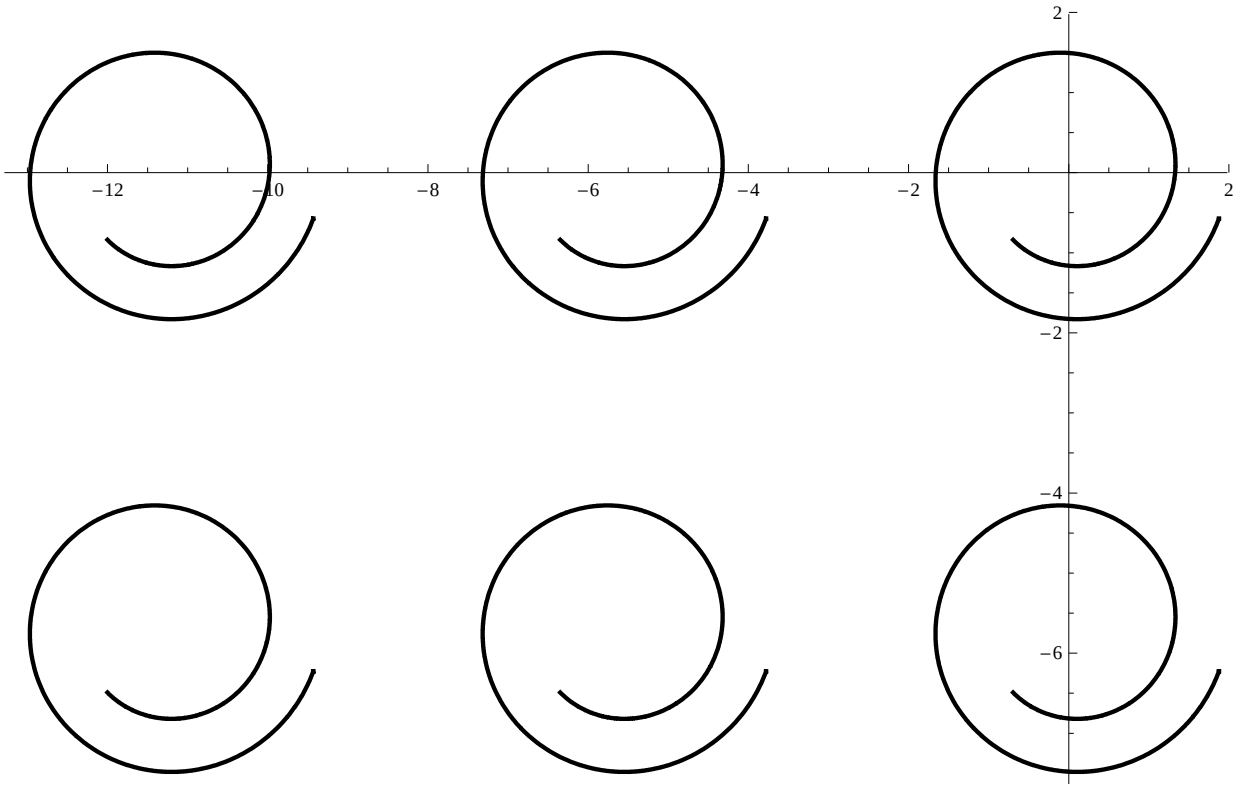


Draw the spirales of the nanoscrolls of the structure:

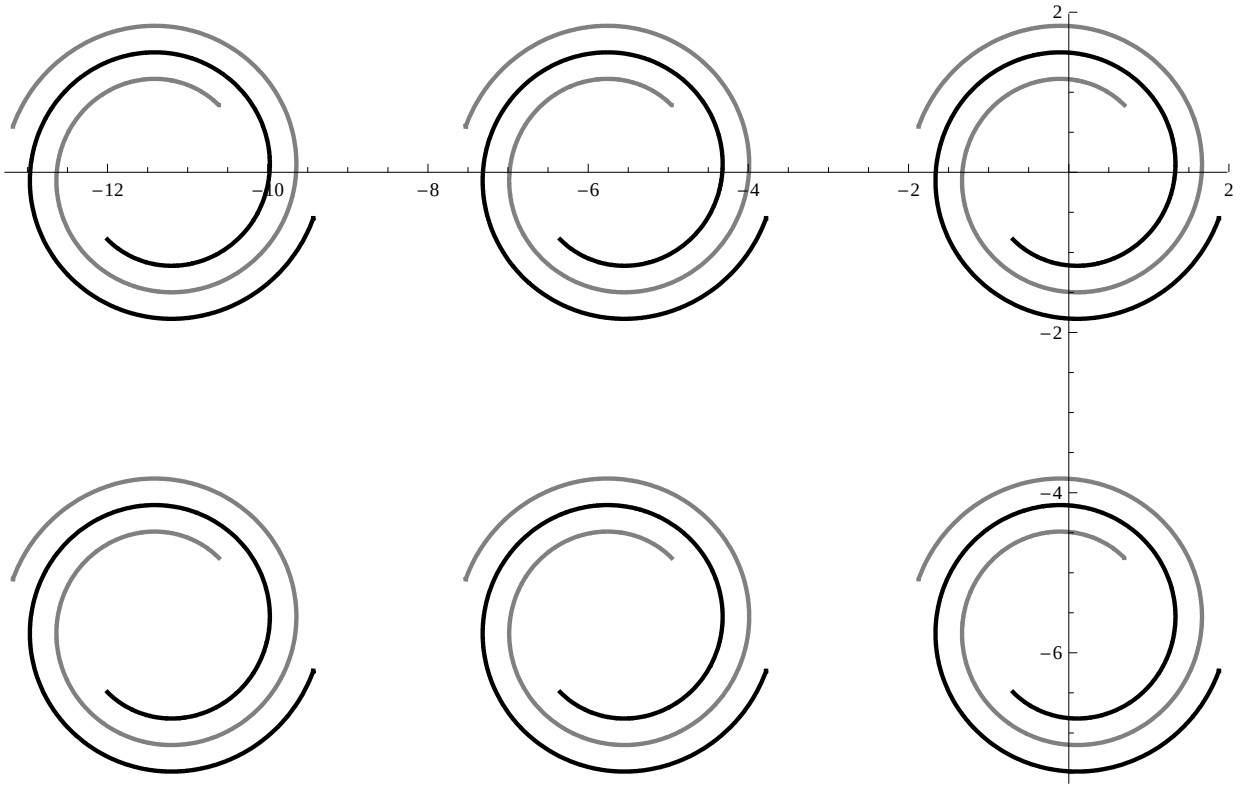
aScrollXZp=5.65304nm

aScrollXZp=2ROut1p+hp+2rNanotubep, {2ROut1p,hp,2rNanotubep}={3.96164, 0.3354, 1.356}

Show[tSpirale1Scroll]:



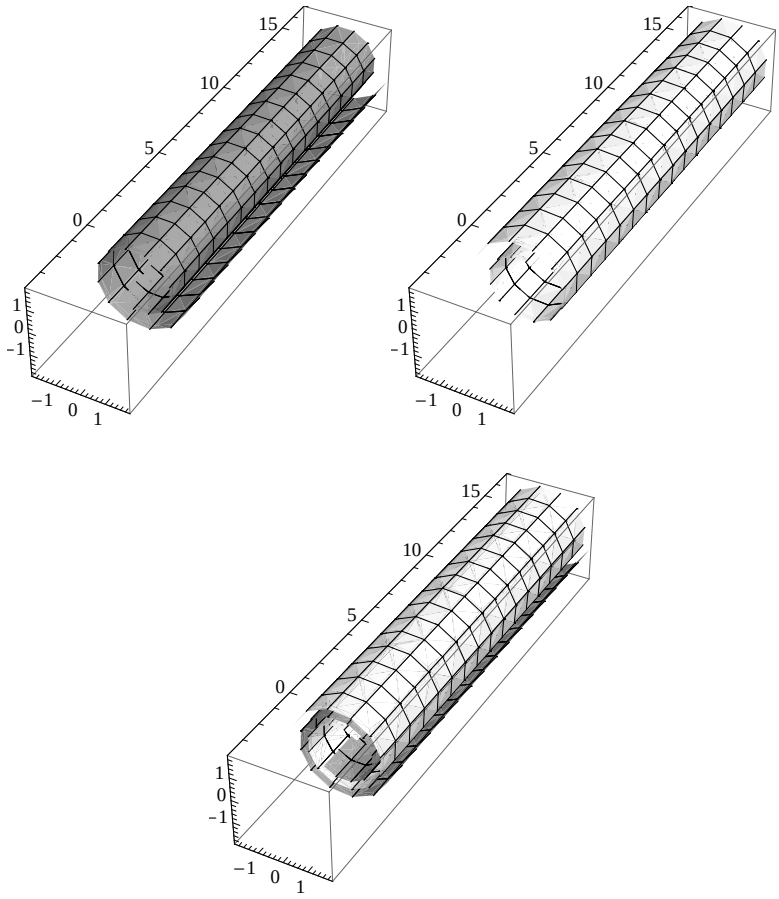

```
Show[tSpirale1Scroll,tSpirale2Scroll]:
```




```
Draw the Nanotubes of the structure:

Define all 3D-scrolls

Show[Scroll13D00], Show[Scroll23D00],                    Show[Scroll13D00,Scroll23D00]:
```



Define tScroll13DXZ and tScrol23DXZ

--------Show the Metamaterial:----------

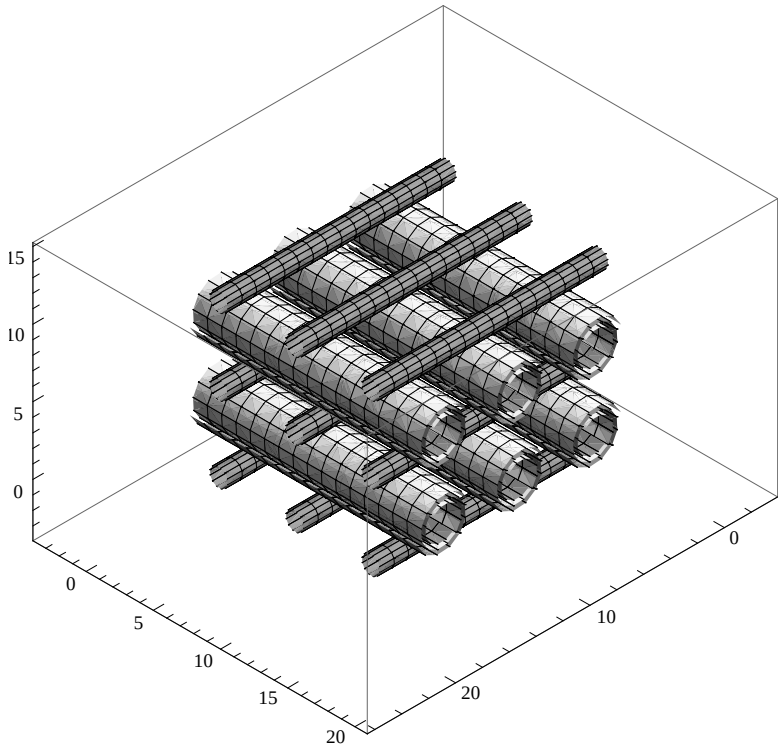
(Fig.4 of the paper

Model of Metamaterial Based on Graphene Scrolls

and Carbon Nanotubes with Negative Refractive Index

/ A.I. Siahlo, N.A. Poklonski, S.A. Vyrko and S.V. Ratkevich

//Semiconductors.– 2018.– V. 52, „ 14.– P.1886 (4 pp.).)



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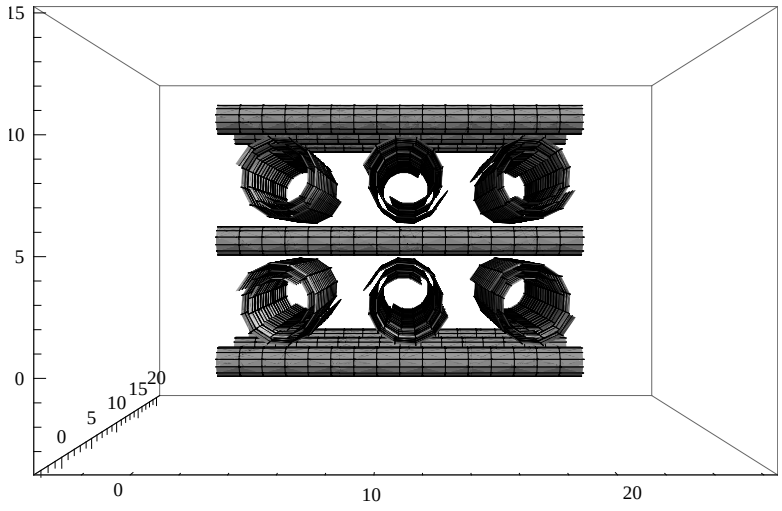
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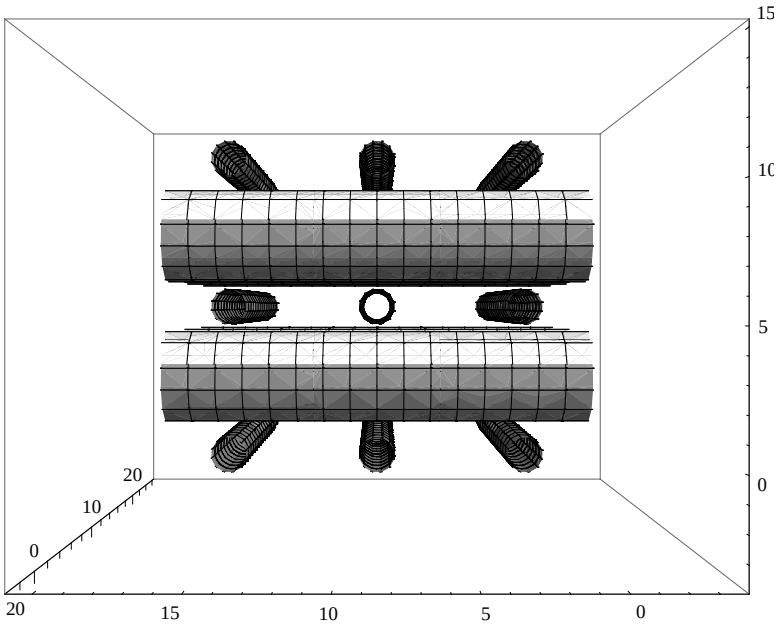
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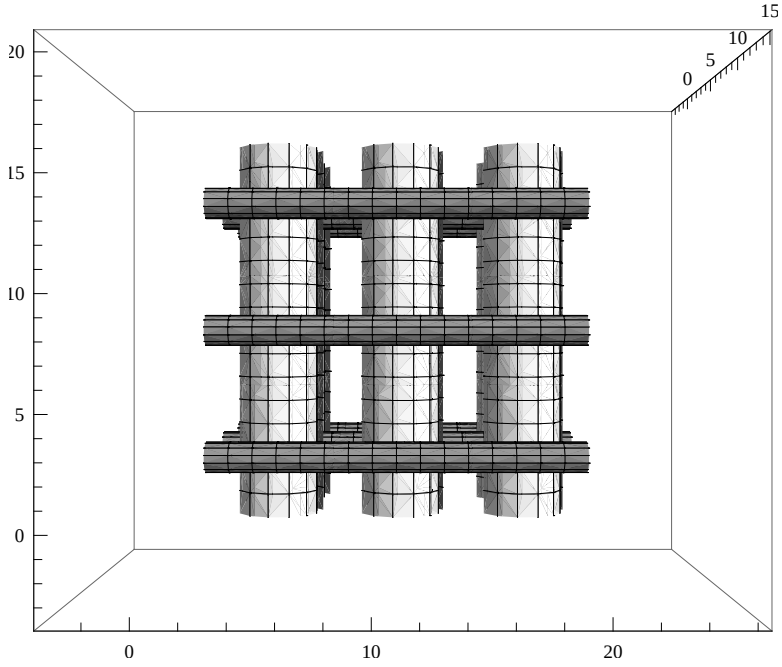
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10
20

The parameters of the metamaterial

```
{nNanoscrollsXp,nNanotubesYp,nNanoscrollsZp,nNanotubesZp}:
```

```
{3, 3, 2, 3}
```