Supporting Information

Genetic Algorithms to Automate the Design of Metasurfaces for Absorption Bandwidth Broadening

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1. The detail of the experiment

The substrate schematic diagram used in the manuscript is shown in Figure S1(a). The upper substrate (i.e. substrate A) is a spherical carbonyl iron polyurethane composite with a volume fraction of 20%. The filler of the bottom substrate (i.e. substrate B) is a flake and spherical carbonyl iron mixture. It is compounded with polyurethane to produce a composite material with a volume fraction of 45%. The electromagnetic parameters of substrate A and B are shown in Figure S1 (d) and (e), respectively. They were combined and placed on the metal backing plate to measure their reflection loss. The bandwidth of which RL over -10 dB covers 4.5-9 GHz. The simulation results and experimental results were shown in Figure S1 (f).

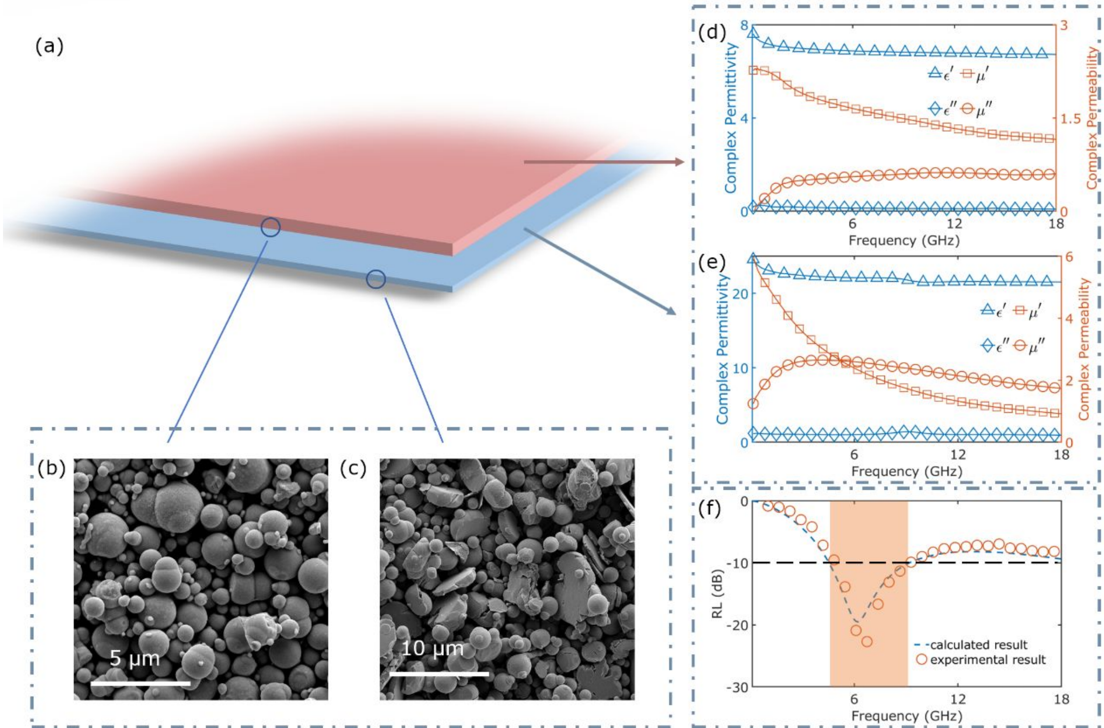

Figure. S1. (a) Schematic of the double-layer substrate; (b) and (c) are the SEM of the filler of the top substrate and bottom substrate, respectively; (d) and (e) are the electromagnetic parameters of the top substrate and bottom substrate, respectively; (f) is the reflection loss from the calculation and experimental.

2. The computational results comparison between HFSS and artificial neural network

In our trained process, the mean square error was set as performance to evaluate the training extent. The change of the MSE with the increase of the training iterations are shown in figure S2. The maximum training iterations are set as 1000 in this process. When finished the training, the MSE reaches 0.204.

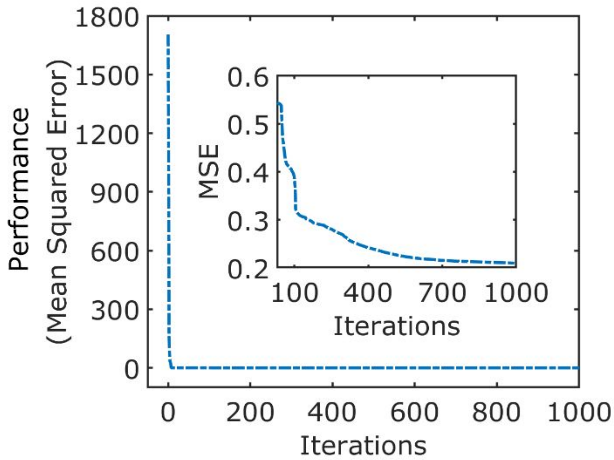

Figure. S2. The performance of the BP neural network (Mean squared error) varies with the training iterations

After obtaining the trained neural network, some arrays (not included in the training data) were randomly generated to verify the accuracy of the neural network. Figure S3 and S4 shows the comparison between HFSS and artificial neural network. In these figures, the blue dotted line represents the simulation results from HFSS and the red circle line represents the calculated results from BP neural network. The inset is the corresponding pattern.

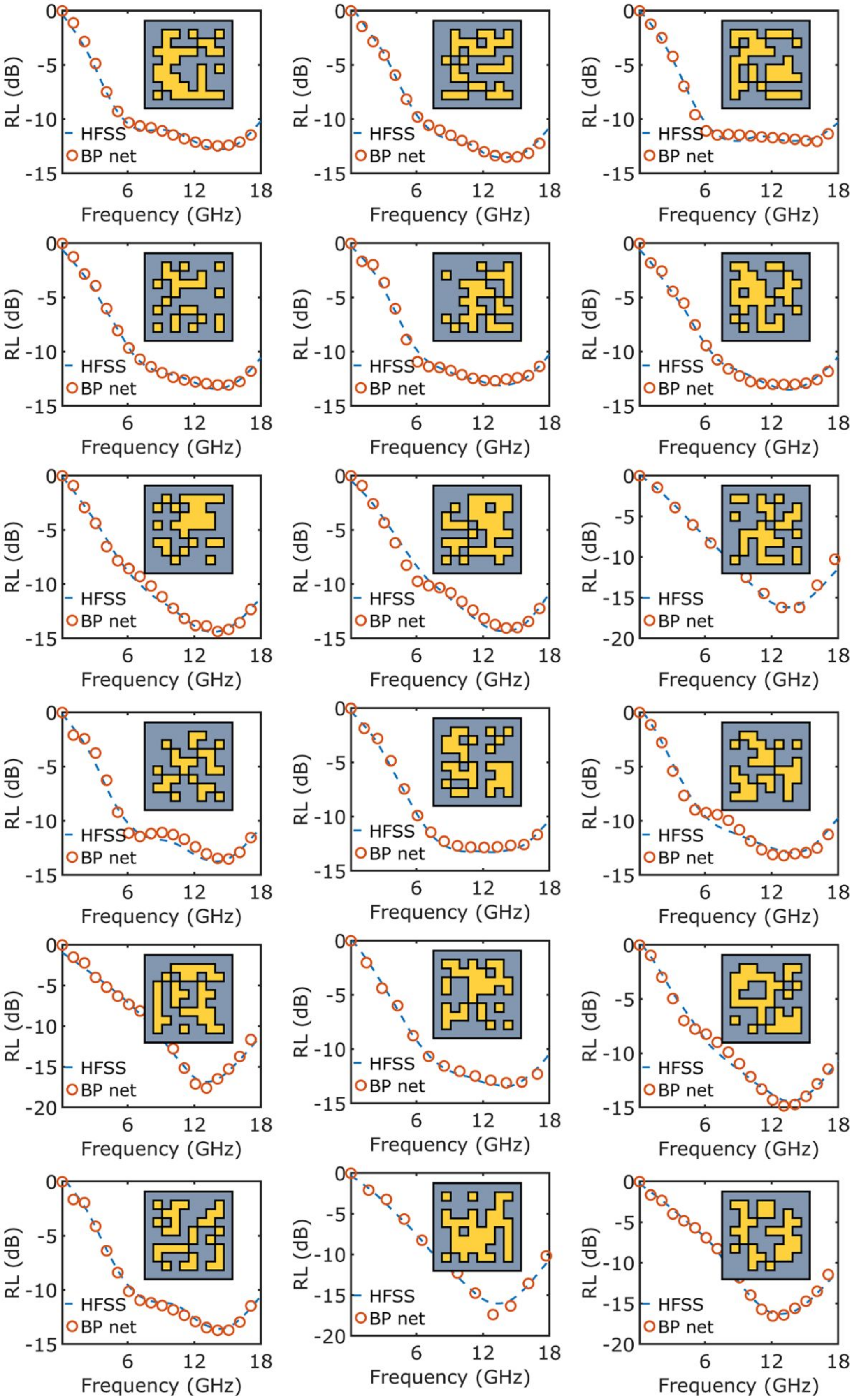
RL (dB)
Frequency (GHz)
HFSS
BP net
0
-5
-10
-15
-20
6
12
18

Figure. S3. The comparison of results from HFSS and trained BP neural network.

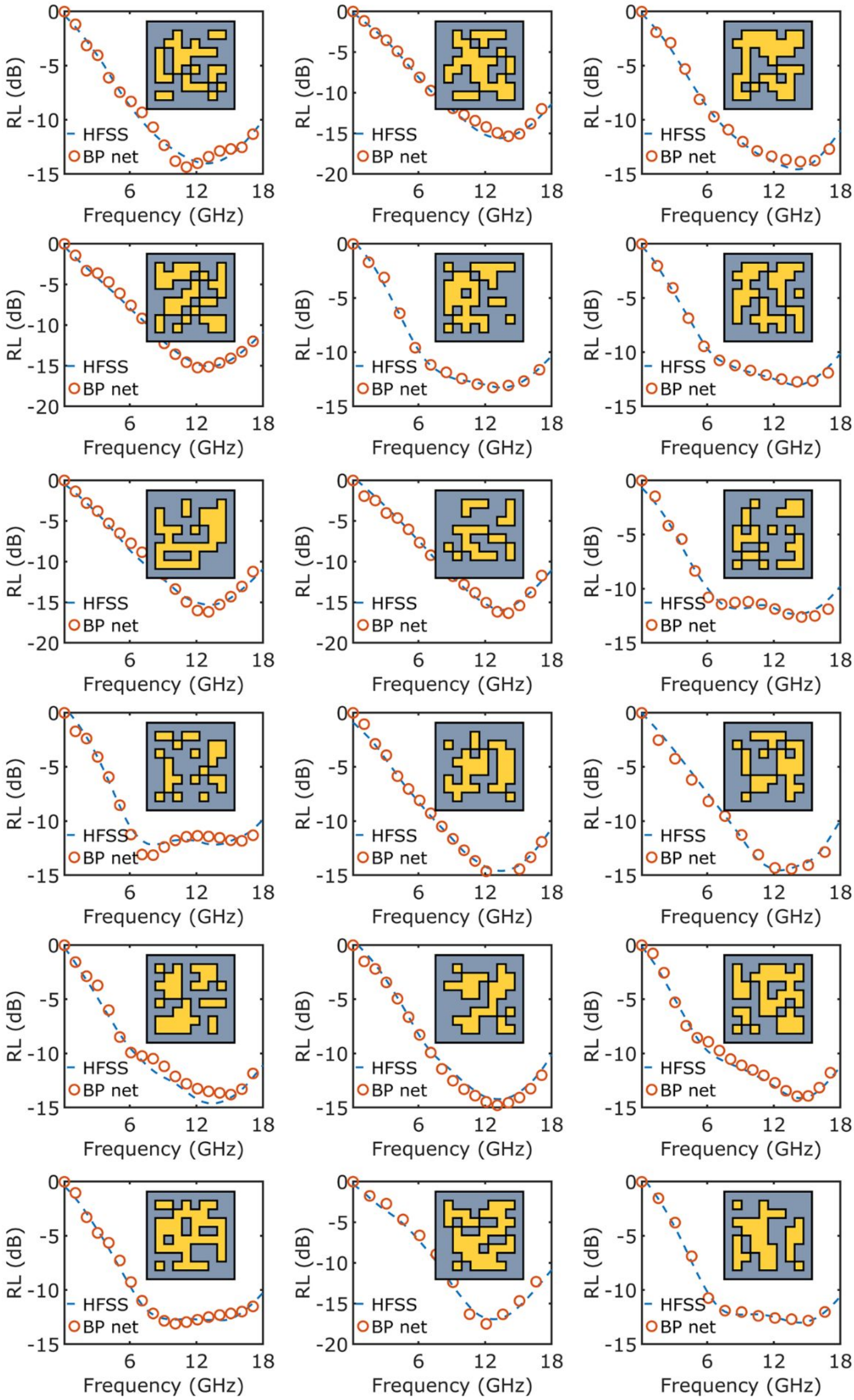

Figure. S4. The comparison of results from HFSS and trained BP neural network for another 18 cases.

3. The investigation of absorption performance for different polarization mode and incident angle

For metamaterial absorber, the absorption performance for the different polarized incident wave is a very important indicator. Because all polarization can be considered as a combination of TE wave and TM wave, the absorption performance for TE and TM wave is used to evaluate the polarization insensitivity. Using HFSS, these two RLs are simulated as shown in figure S5 (in which mode 1 represents the TE mode and mode represents the TM mode). Although the metamaterial shows a good absorbing bandwidth (covering 6-18 GHz) in the TM case, it does not perform as well as the performance of the TE case.

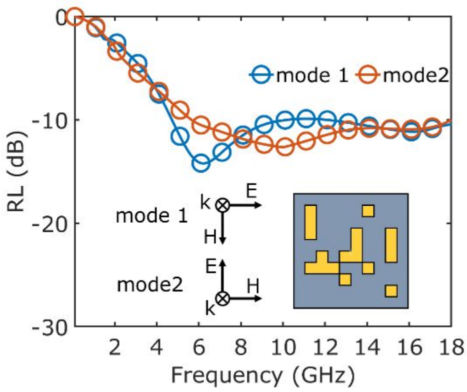

Figure. S5. The comparison of absorption performance for different polarized incident wave.

We have also simulated the dependence of absorption performance on the incident angle, as shown in Figure S6. When the incident angle is less than 30 degrees, the absorption performance keeps nearly unchanged. When beyond 30 degrees, there is a clear difference between TE and

TM mode. For TE mode, with the increase of the incident angle, the RL will increase. However, for TM mode, the RL will decrease with the increase of the incident angle.

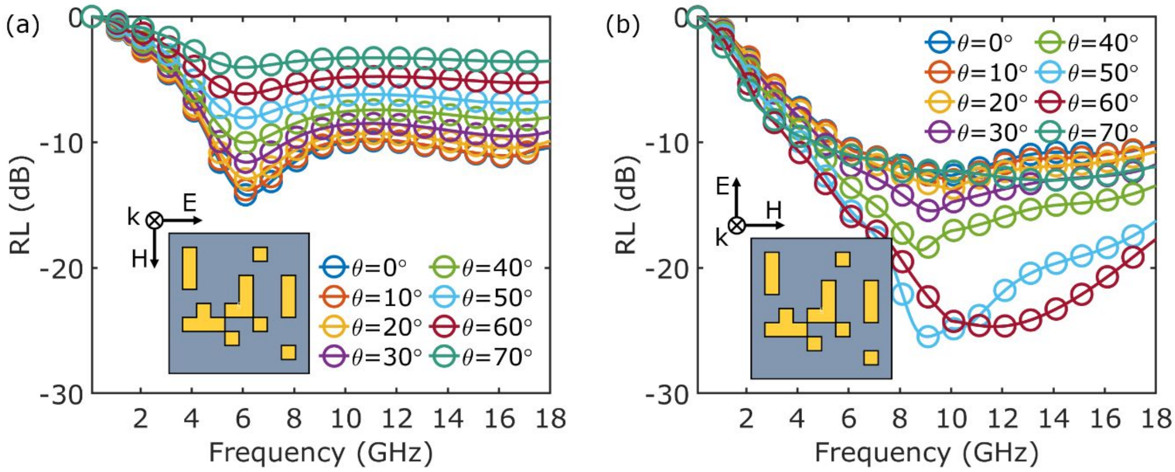

Figure. S6. The comparison of absorption performance in different incident angles.

4. The investigation of the effect of different metal on absorption performance

We have simulated the effects of different array materials (silver, gold or aluminum) on the absorbing performance. The results are shown in figure S7. From the simulated results, the change of array metal does not affect the absorbing performance. This could be explained as follows: When the incident wave meets the metasurface, the free electrons in the metal array will be excited. The movement of the free electrons produces the secondary waves, which will affect the waves entering the substrate and lead the adjusting the absorption performance. After deciding the array pattern, as long as enough free electrons are supplied, the resulting secondary waves are the same as each other. These materials, including gold, silver, aluminum, and copper, all have high electrical conductivity. They all can provide enough free electrons so that changing the array material doesn't make a difference.

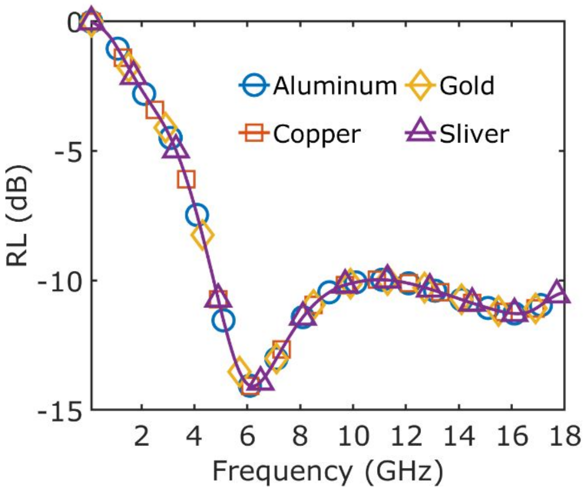

Figure. S7. Comparison of RL for metasurface in different metal materials.