Supplementary Materials: Effects of Microsphere Size on the Mechanical Properties of Photonic Crystals

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Section I: Modeling Details in FEM Simulations

The FEM simulations of the nanoindentation process of the PCRs were performed using the commercial finite element software ABAQUS Version 6.11(Dassault Systems, France). The simplified model of the nanoindentation was presented in Figure S1, consist of Berkovich tip and specimen. The indenter was defined as a rigid body with one free displacement direction, and the other degrees of freedom was constrained. The bottom surface of the specimen was constrained in all degrees of freedom. The model in Figure S1 was developed using CPS3 elements. The mesh was divided by triangle, and the total number was 7290. The tip was loaded by a displacement applied to its reference point. The rigid tip could move only in the vertical direction. The specimen material used elastic-perfectly plastic constitutive model and von Mises yield criterion.

FE analyses accounted for geometric nonlinearity (i.e., significant deformation). The automatic time-stepping option facilitated convergence of nonlinear analysis. The contact between the indenter and specimen was assumed to be frictionless, and the "Hard Contact" option available in ABAQUS was selected. Interactions between microsphere elements of the model were defined using "General Contact" option.

Section II: The Simulation Curves under Different Indention Depth

The simulation curves of five microsphere sizes, concerning the maximum displacement of 200 nm, 300 nm, 400 nm, 530 nm, are shown in Figure S2 a,e. As seen in Figure S2 a,e, both the simulation curves are not smooth, and there is some jump phenomenon (pop-in) existing to a greater or lesser extent in the curves. It can be seen that: At the maximum indentation depth, with five microsphere size PCs, the curves obtained from the simulation are consistent with the load-displacement curves measured in the test. It is concluded that there are certain deviations in the later stages of the experiment loading curves and the simulation curves. This is because the PCs belong to FCC arrangement in space. It is caused by the sliding, squeezing, and other interactions between the microspheres in the film during the pressing-in process of the indenter.

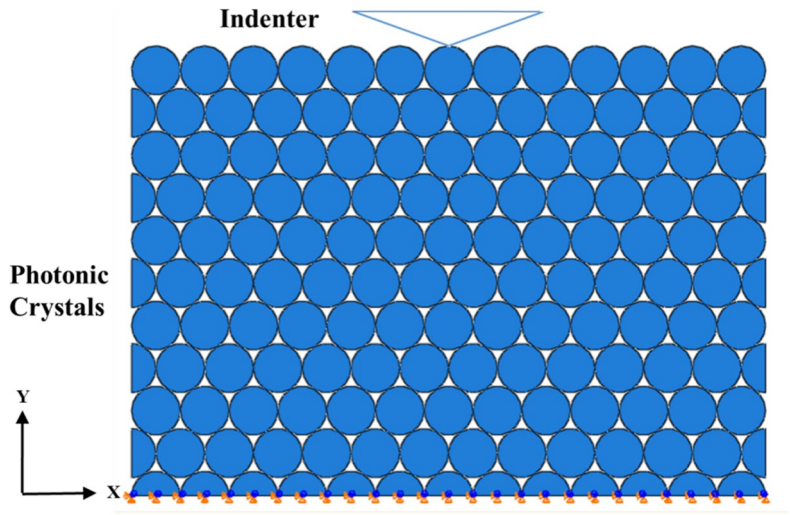
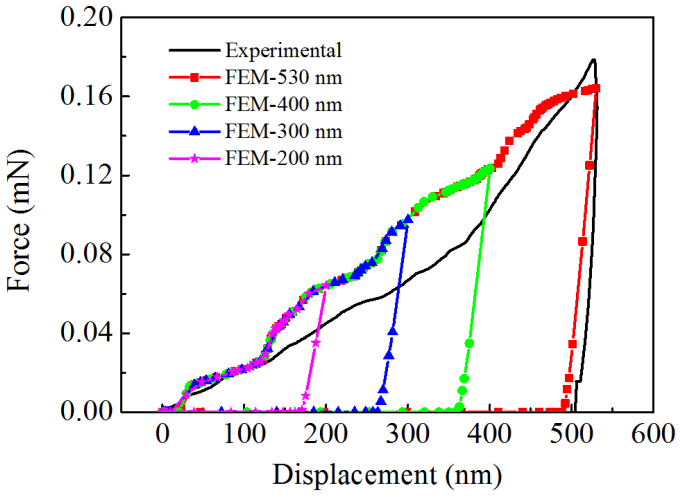


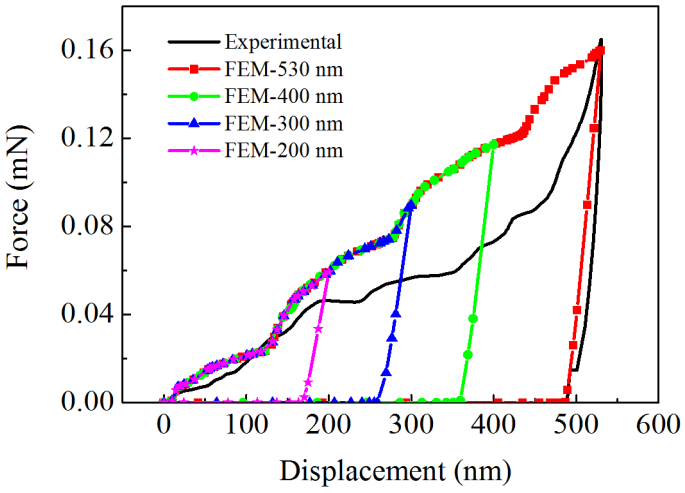
Figure S1. The geometric model of colloidal crystals.

a)


Experimental
FEM-530 nm
FEM-400 nm
FEM-300 nm
FEM-200 nm
Force (mN)
Displacement (nm)
0.00
0.04
0.08
0.12
0.16
0.20
0
100
200
300
400
500
600

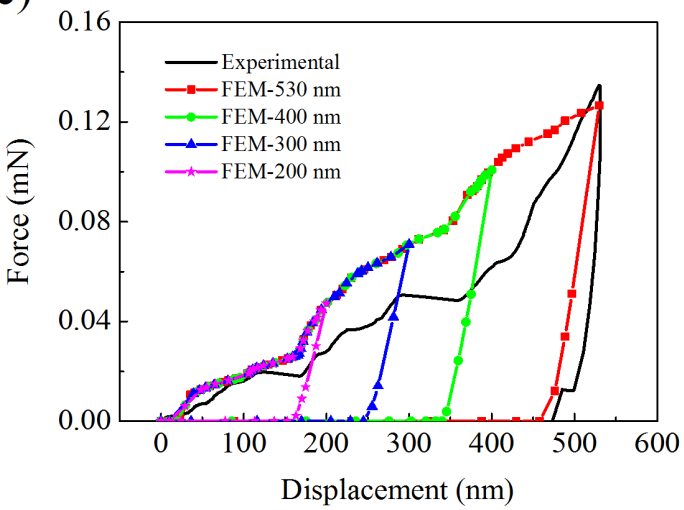
(a)

b)

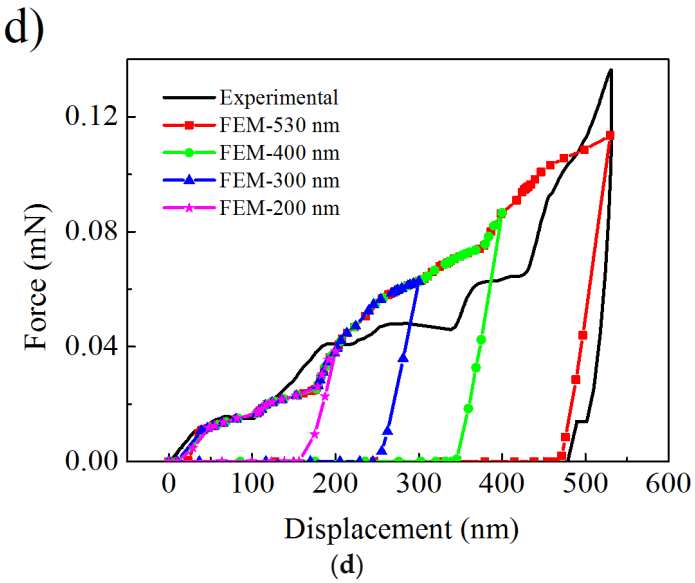

Experimental
FEM-530 nm
FEM-400 nm
FEM-300 nm
FEM-200 nm
Force (mN)
Displacement (nm)
0.00
0.04
0.08
0.12
0.16
0
100
200
300
400
500
600

(b)

c)


Experimental
FEM-530 nm
FEM-400 nm
FEM-300 nm
FEM-200 nm
Force (mN)
Displacement (nm)
0.00
0.04
0.08
0.12
0.16
0
100
200
300
400
500
600

(c)



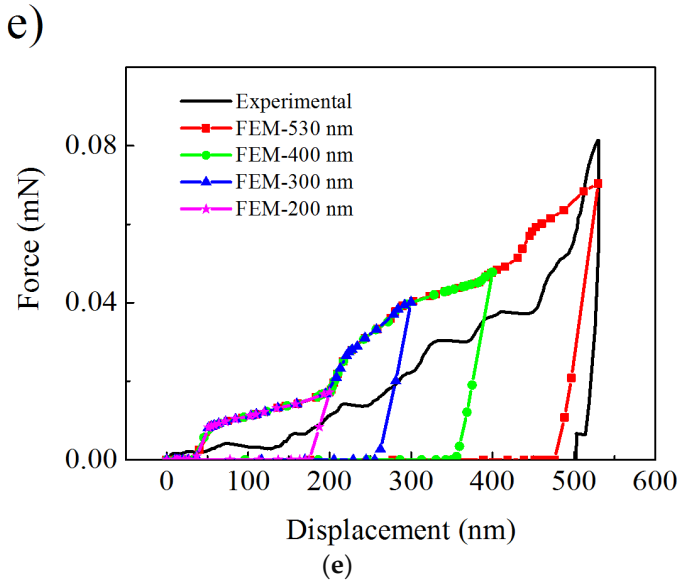


Figure S2. The simulation curves under different indention depth (**a**) 326nm, (**b**) 347nm, (**c**) 438nm, (**d**) 470nm, (**e**) 538nm.