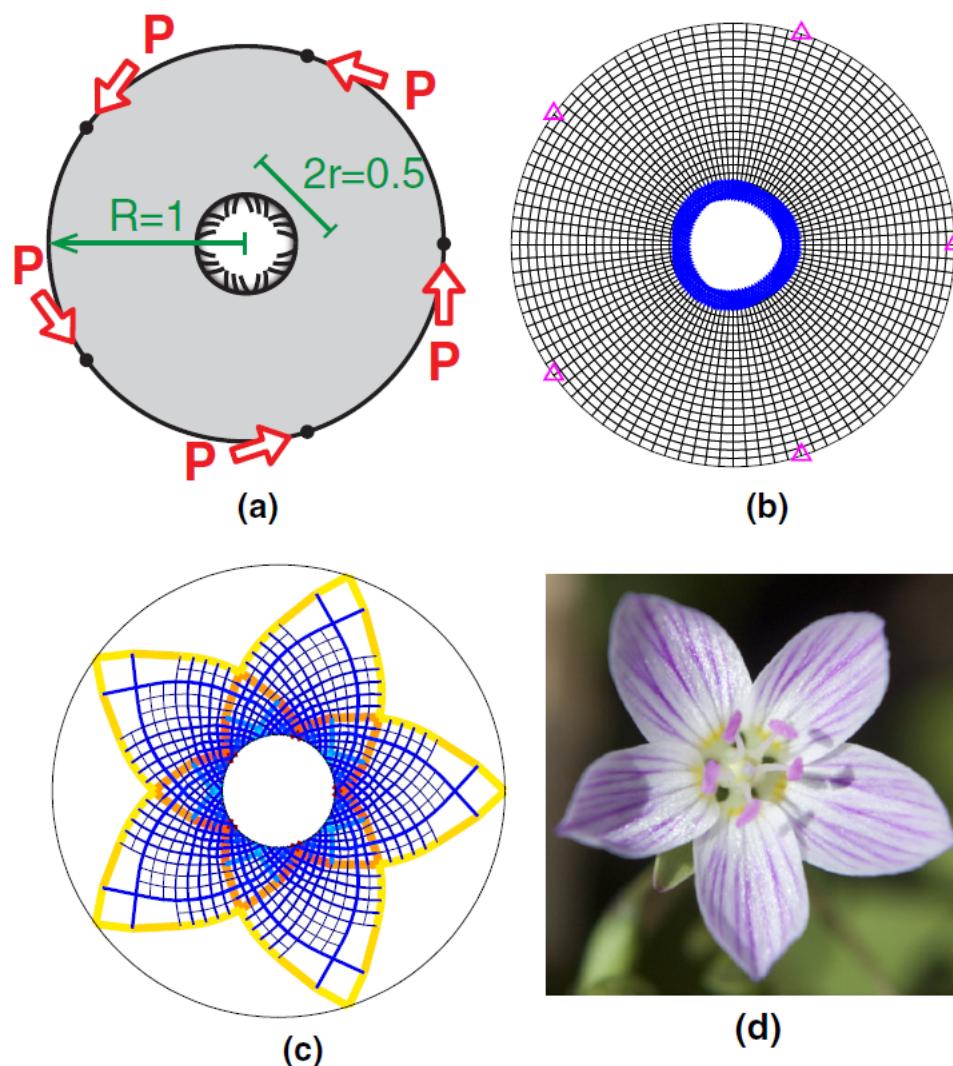


# 介绍：问题描述-拓扑优化

功能驱动的设计

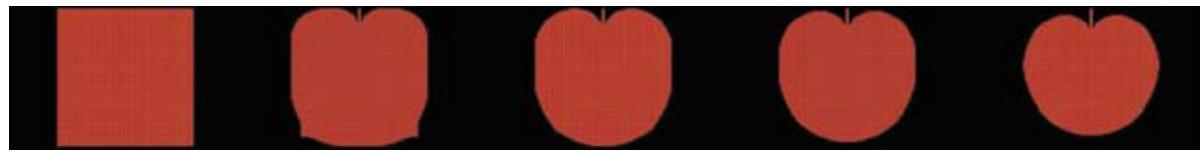
# Topology optimization- Demonstration

**Fig. 1** Tangentially loaded donut-shaped domain. **a** Domain, loading and boundary conditions. **b** Base-mesh (discretization) used to construct the ground structure. **c** Optimized ground structure. **d** Photo of *Claytonia caroliniana* [© Nathan Masters — Masters Imaging]

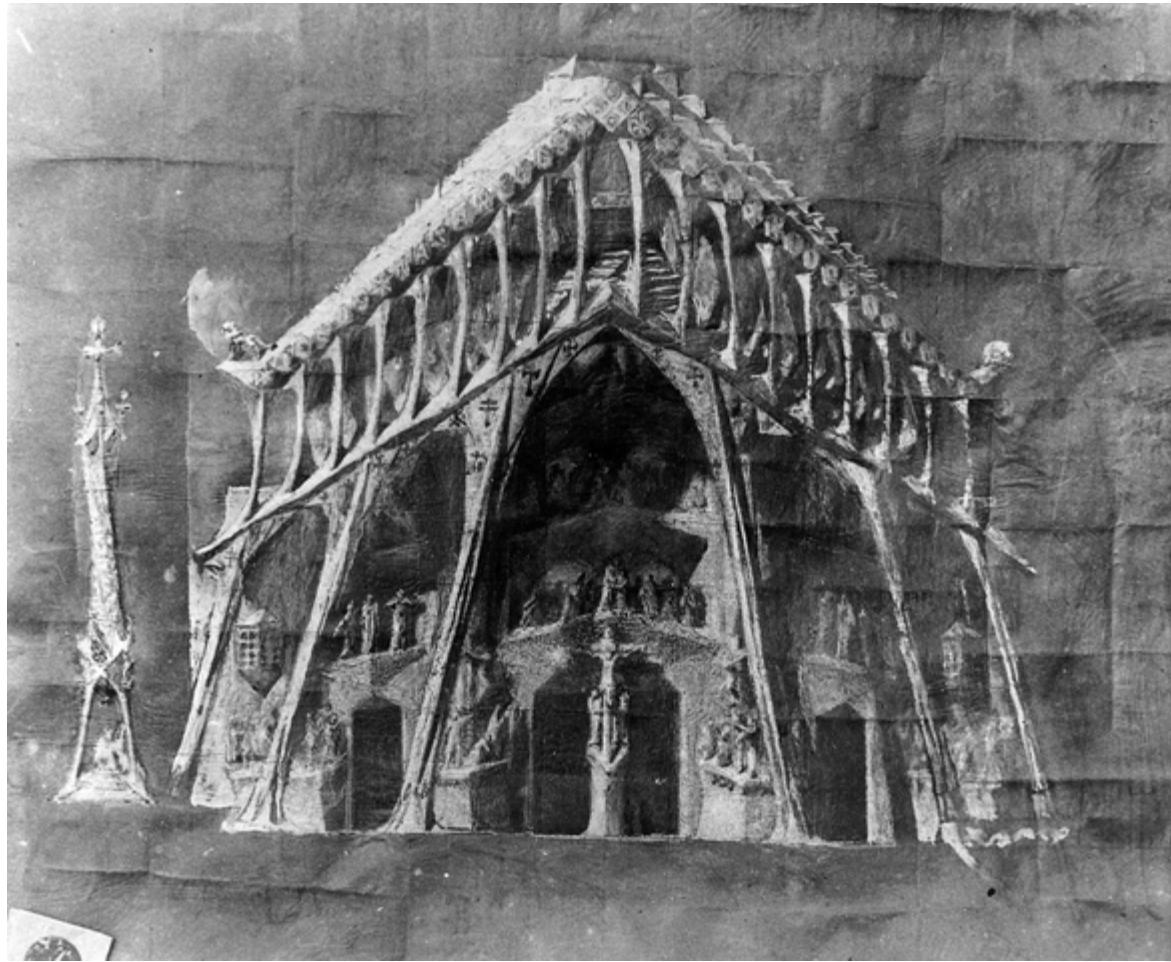


# Topology optimization- Demonstration

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# Topology optimization- Demonstration

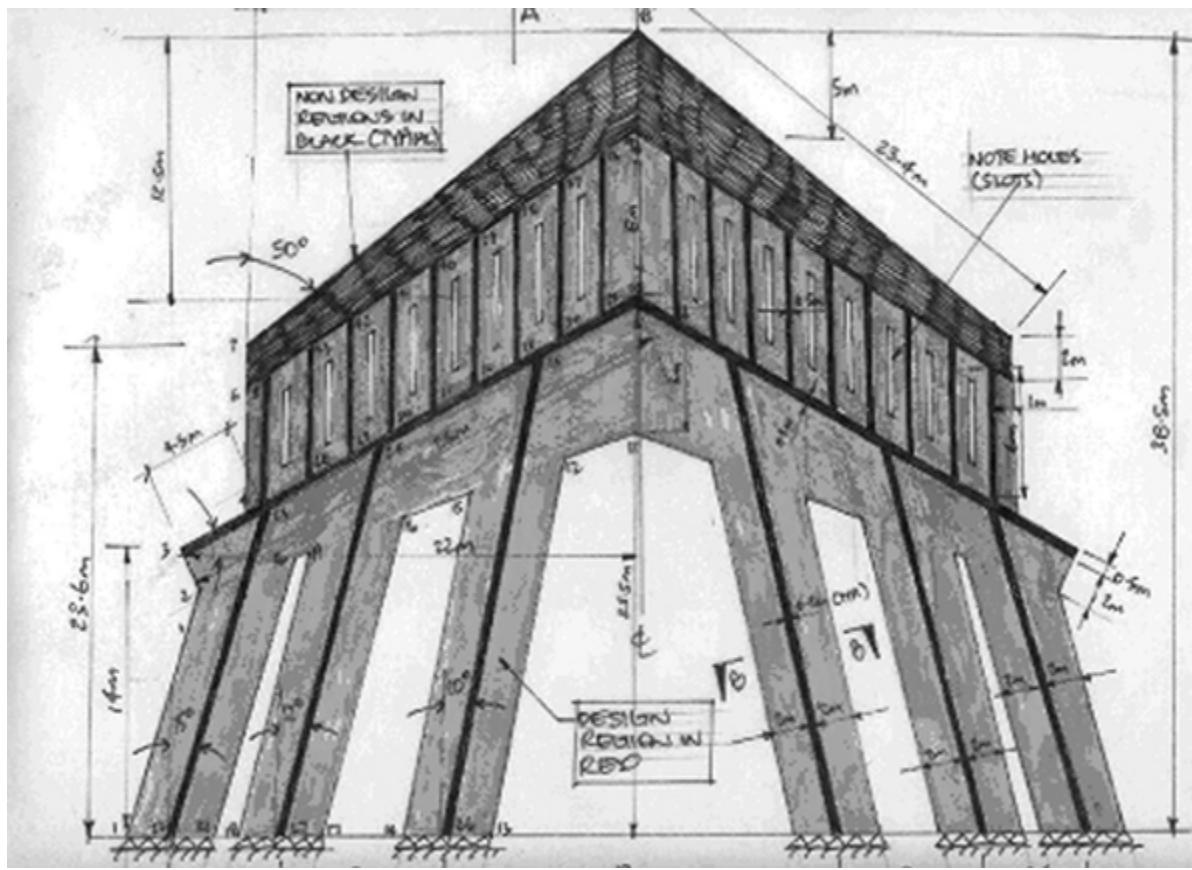


受难门(高迪)

圣家堂是他最伟大的作品，他把一生中的43年都贡献在那里，1925年还干脆搬到教堂的工地去住，全心全意研究教堂的结构设计。

1926年6月7日的下午，高迪完成当天的工作从圣家堂到市中心的教堂做礼拜，被一辆电车撞倒，当时他衣衫破旧，路人以为是流浪汉，把他送到圣十字医院，三天后去世了，大家才发现流浪汉竟是高迪，为他举行了很隆重的葬礼，送葬的队伍从圣十字医院一直缓缓的延伸到了圣家堂，把他安葬在他未完成的圣家堂地下。

# Topology optimization- Demonstration



# Topology optimization- Demonstration



图3展现了立面演进的过程。最终的结果可以被认为是在特定的边界支撑、材料用量以及材料类型（该案例中是砌块）的情况下，最为有效的传递重力荷载的结构形态。就像在高迪的原稿中提到的一样，每一根下部的柱子都支撑着一组完整的分支的上部柱子。有趣的是，无论上部还是下部支柱，都拥有着骨头一般的造型。或许高迪对于最优的结构形态有着非比寻常的洞察力，他设计的很多结构都具有极高的效率。



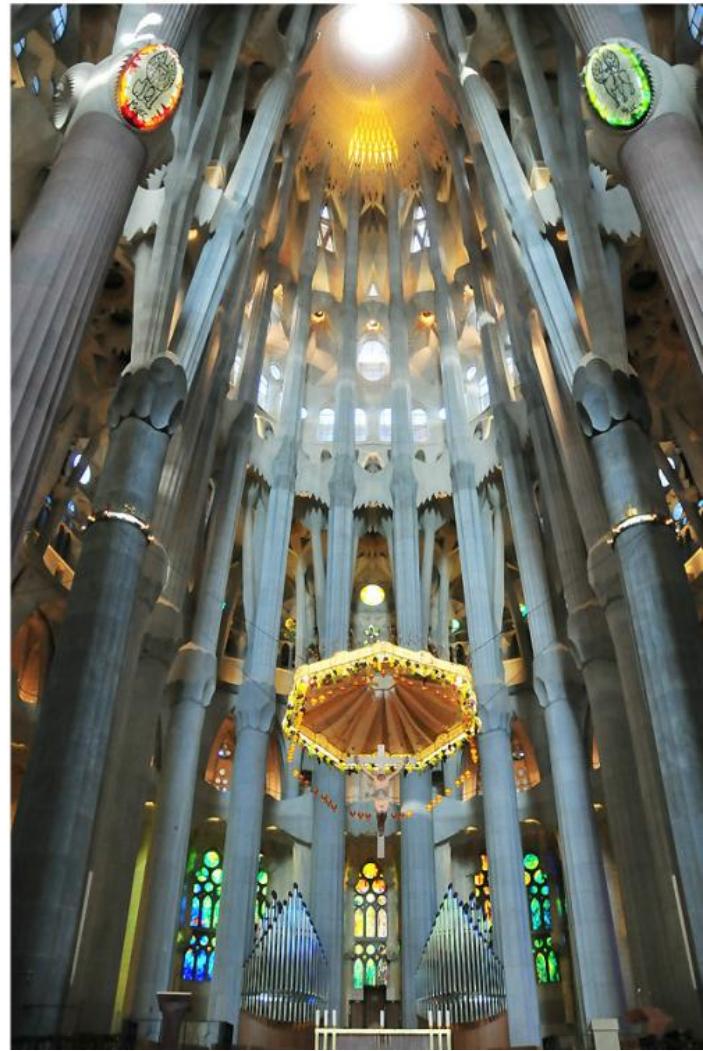
# Topology optimization- Demonstration

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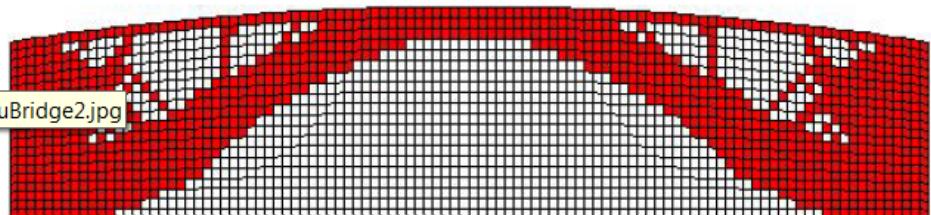
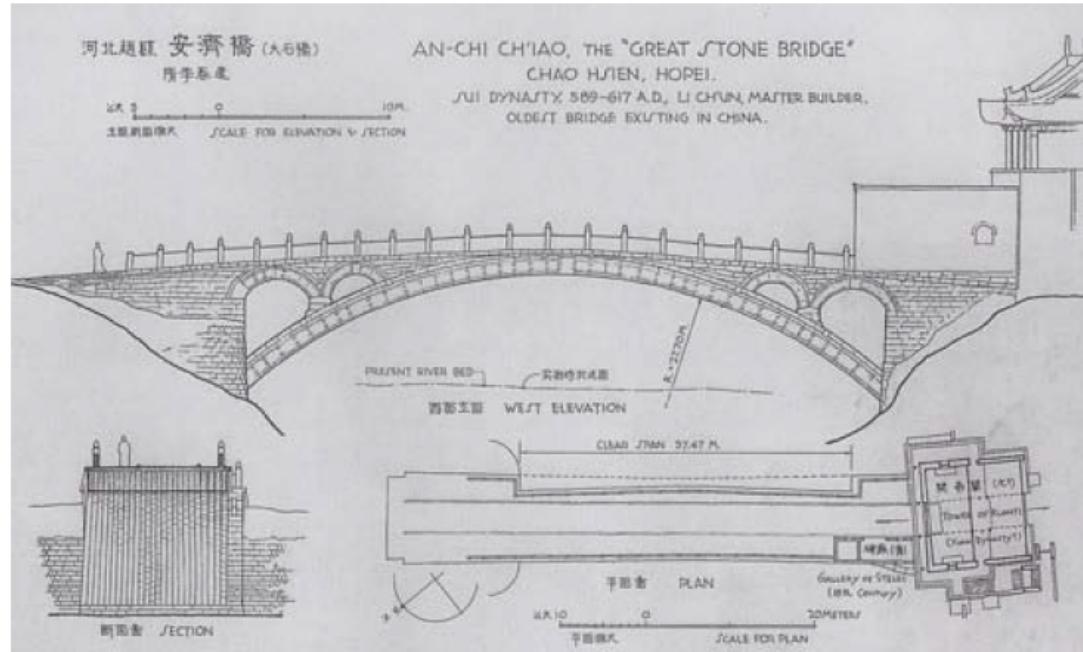


# on- Demonstration

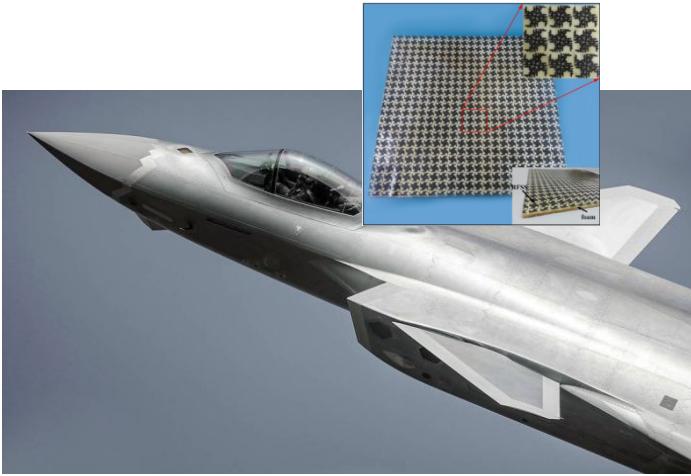
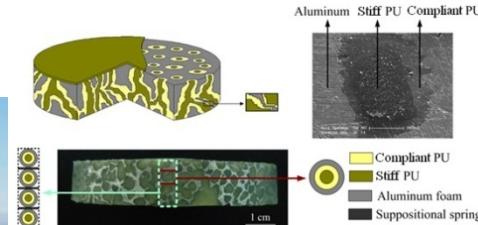
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# Topology optimization- Demonstration

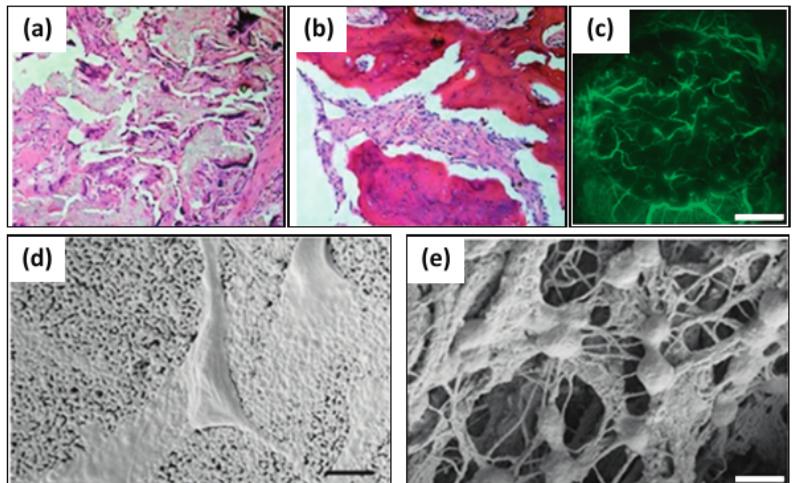


# 微结构模型

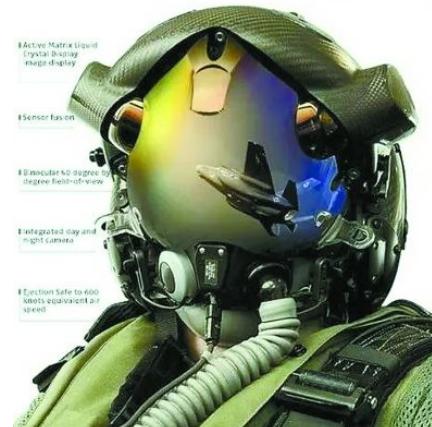


水下吸波消声瓦（吸收降低噪音）

隐身材料(屏蔽电磁辐射)

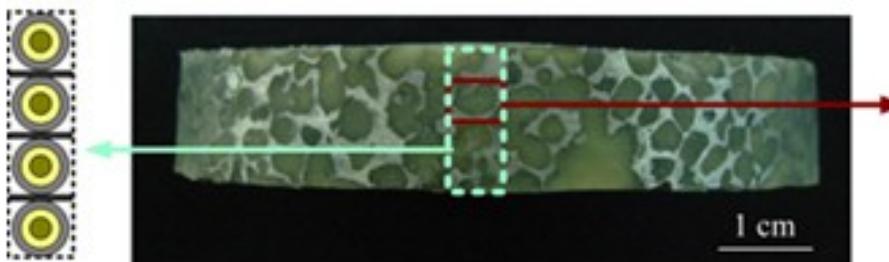
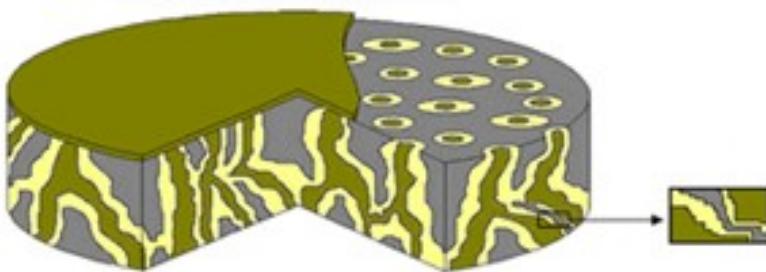


骨头生长培养

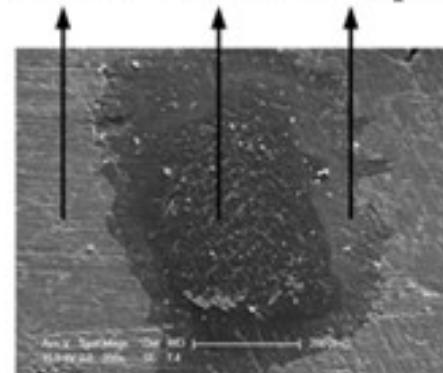


吸收冲击能量

# 微结构模型

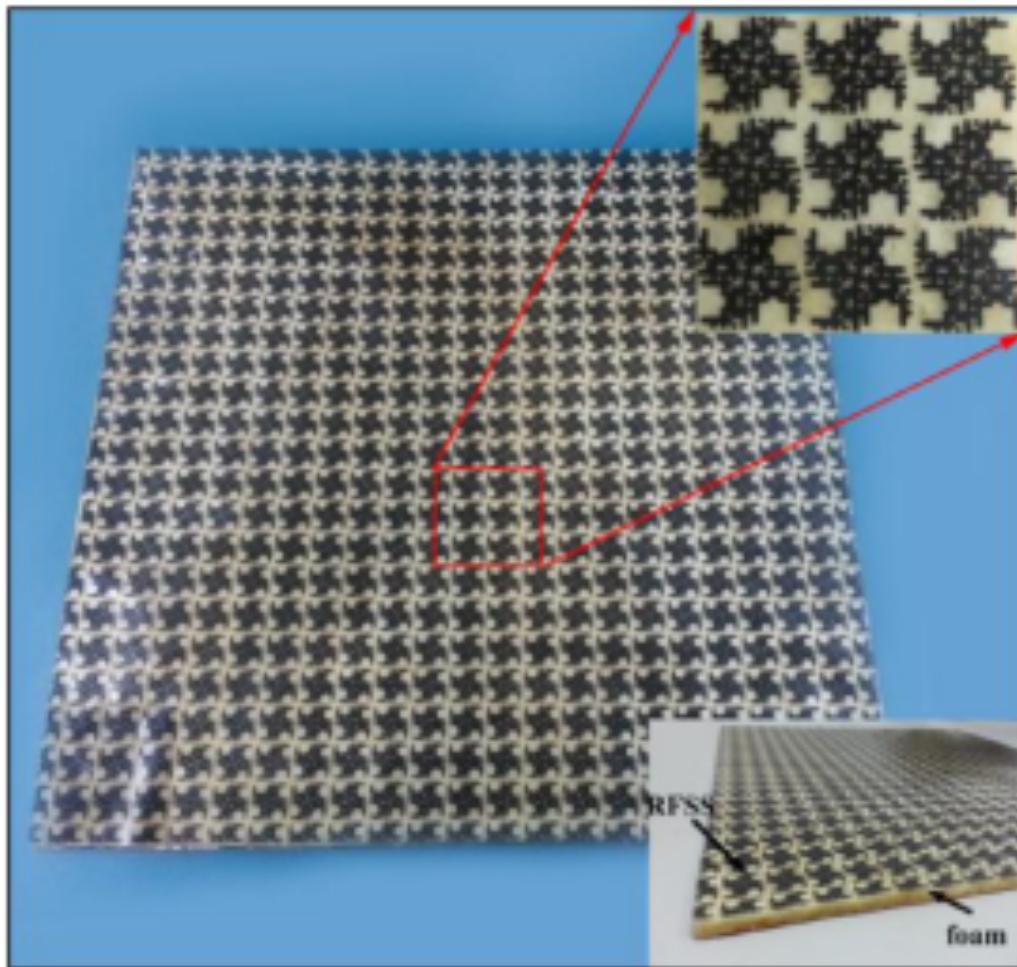


Aluminum Stiff PU Compliant PU

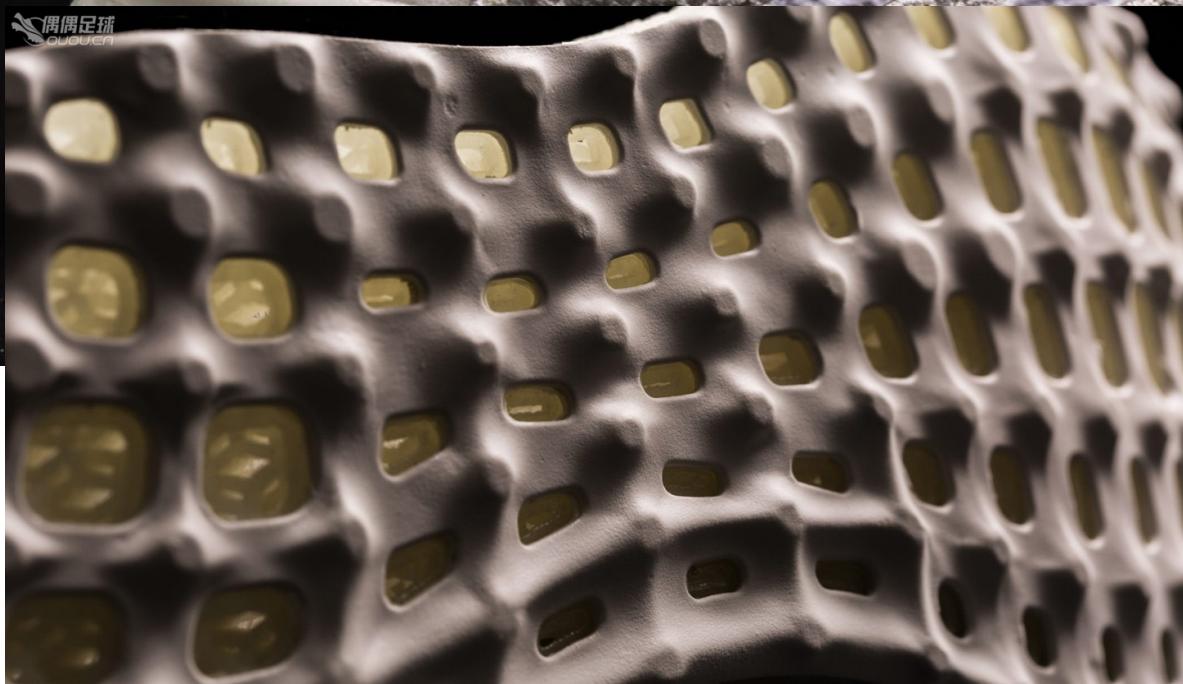


- Compliant PU
- Stiff PU
- Aluminum foam
- Suppositional spring

# 微结构模型

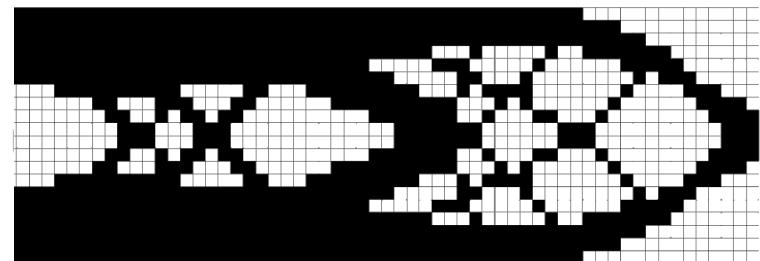
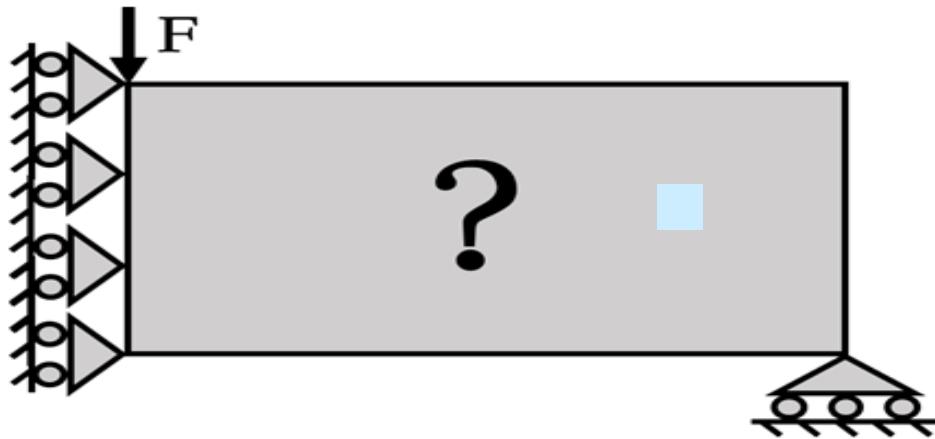


隐身材料(屏蔽电磁辐射)



# 介绍：问题描述-拓扑优化

## 单尺度拓扑优化

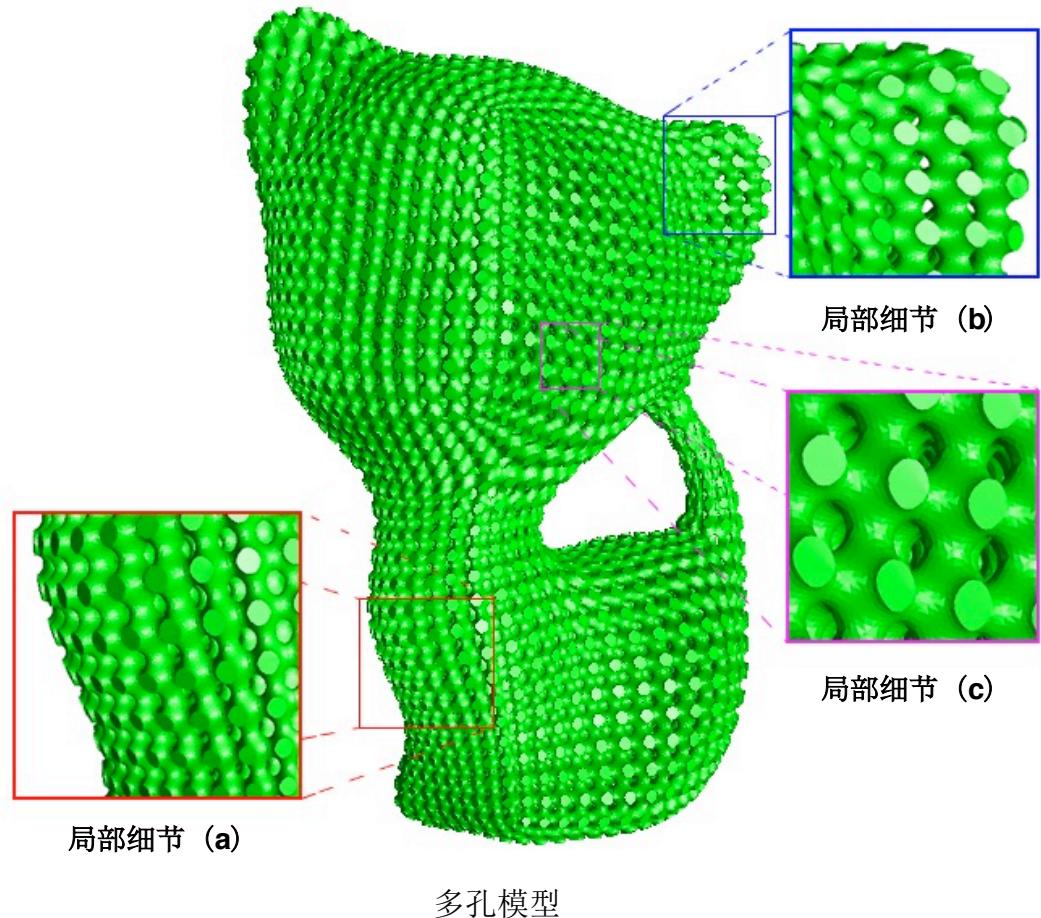


优化目标:  $O(X, U)$   
设计变量:  $X = \{0, 1\}$   
平衡方程:  $K(X)U = F$  or  $U = \arg \min A(U, X)$   
材料约束:  $(X, V) \leq V_0$

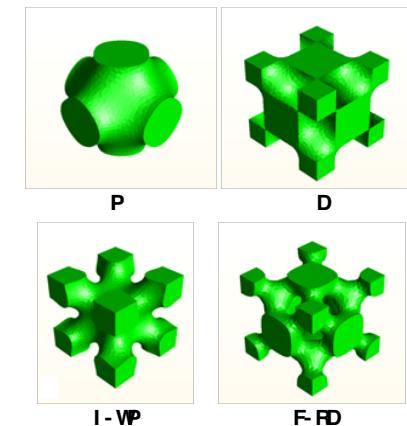
$X$ : density;  
 $U$ : displacement;  
 $K(X)$ : stiffness matrix;  
 $V_0$ : target volume;

有限元仿真  
离散优化算法

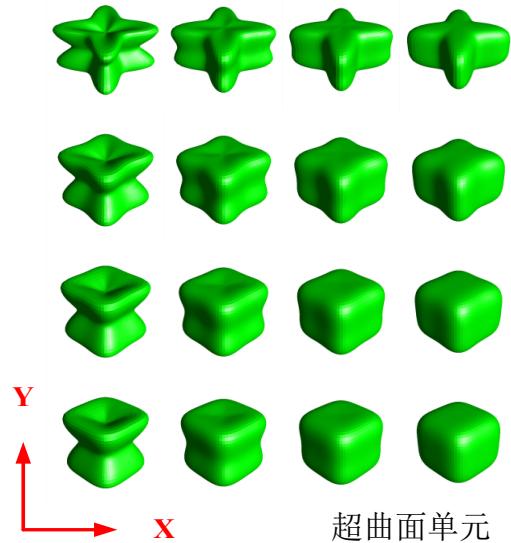
# 介绍：问题描述-多孔拓扑设计优化



如何有效设计宏观结构、微观材料结构



周期性极小曲面单元



超曲面单元

# Topology optimization- Introduction

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- Parameter optimization
- Shape optimization
- Topology optimization
- Optimization algorithms

Refer to PDF for more details

# Solving Linear Equation System

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- $ax=b$ ,  $a,b,x$  are real number
- $Ax=b$ ,  $A$  is a square matrix,  $b,x$  is a vector
- when  $a$  is of large size
- when  $A$  is a sparse matrix
- the convergence rate

# Solving Linear Equation System

---

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- when  $A$  is a sparse matrix
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# Solving Linear Equation System

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- Solution expression
- Direct approach: Gauss elimination, LU decomposition
- Iterative approach: Jacobi, Gauss-Seidel, Steepest decent, Conjugate gradients

# 线性方程组求解

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- Condition number
- KKT condition
- Conjugate gradient
- Multi-grid and MGCG
- Lagrange multiplier