

# Inorganic Templating of Pollen for Use as Catalytic Material

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## Introduction

Catalytic materials that are both efficient and abundant are vital in sustaining and advancing technological progress. A variety of processes related to chemical synthesis, removal, or passivation of chemical byproducts require catalysts. An effective catalyst is characterized by its high surface area per unit mass, high surface free energy, and/or particular surface chemistry. Ongoing attempts at synthesizing high surface area particles through introduction of significant particle porosity suffer from problems of reproducibility. In an effort to avoid complications associated with porous particle synthesis, a new technique utilizing abundant, natural pollen as templates is investigated. Pollen particles are abundant, easy to obtain, and occur in a large variety of complex geometries (Figure 1) and sizes, some of which possess significant surface area per unit mass.

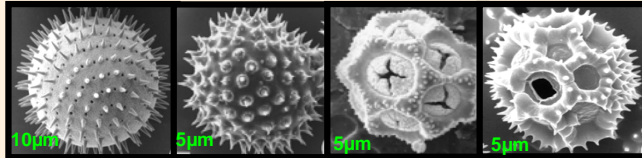


Figure 1: Examples of the variety and geometric complexity of pollen  
*Pollen.usa.gov*

## Objectives

Develop a process that utilizes *Salix* (willow) pollen as a template for thin layers of  $Al_2O_3$ , in order to produce inorganic particles with the following characteristics:

- 1) External and internal structure mimicking that of the original
- 2) Minimal to zero weight percent carbon and other organic content
- 3) Large surface area per unit mass
- 4) Producing on an industrial scale

## Approach

Pollen that has been cleaned and heated for several hours serves as an organic template for nanometer-thin  $Al_2O_3$  layers, deposited using atomic layer deposition (ALD). This results in an inorganic shell conforming to the inner and outer walls, as well as the pores of the pollen particles. Due to the large difference in volatilization temperatures between the organic template and  $Al_2O_3$  shell, the organic is removed via heating of the pollen/ $Al_2O_3$  complex. This process (Figure 2) produces  $Al_2O_3$  replicas of the original pollen particles, maintaining the structure, porosity, and high surface area per unit mass.

## Templating Process

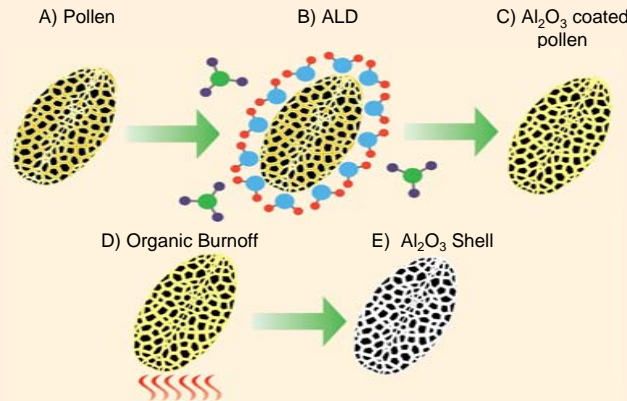


Figure 2: Schematic representation of  $Al_2O_3$  pollen synthesis process with A) *Salix* pollen B) reacting with  $AlCl_3$  and  $H_2O$  precursors resulting in C) pollen coated alumina. The  $Al_2O_3$  coated pollen is D) heated at 700-800°C in air, producing E) an  $Al_2O_3$  replica.

## Results

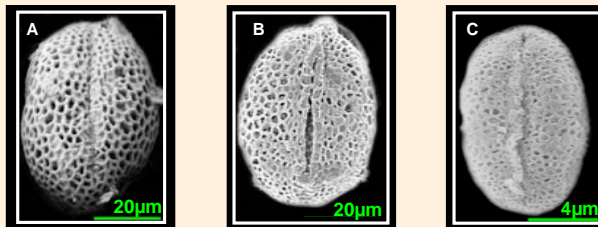


Figure 3: Scanning electron microscope (SEM) images of *Salix* pollen A) before coating, B) after coating with 10nm of  $Al_2O_3$ , and C) after burnoff of organic matter

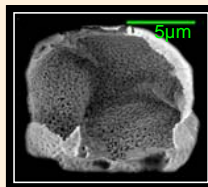


Figure 4: SEM image showing interior of  $Al_2O_3$  pollen particle that has undergone burnoff



Figure 5: EDX Analysis of burnt coated pollen from Figure 3C indicating weight percent elemental composition

## Discussion

Visual comparison between the raw *Salix* pollen (Figure 3A) and the 10nm  $Al_2O_3$  coated pollen (Figure 3B) indicates that the initial steps of the templating process described in Figure 2 maintain the initial structure of the pollen. Upon burnoff (Figure 3C), the pollen undergoes significant shrinkage but does not lose its original topography. In addition to keeping the original external structure, Figure 4 shows that the rough internal walls of the original pollen are successfully replicated. According to the EDX analysis (Figure 5), only a small amount of residual carbon remains after the burnoff process. However, there is a significant amount of alkaline salt present after the burnoff, possibly due to contamination.

## Conclusions

Atomic Layer Deposition provides an effective method for efficient, inorganic templating of organic materials. While only one species of pollen has been examined, ALD is suitable for the synthesis of catalytic particles derived from natural sources. Although shrinkage occurs during the burnoff process, the overall topography of the particles is maintained. Measurements of surface area per unit mass still need to be performed to determine the potential catalytic utility of the particles. The burnoff process effectively removes the majority of the organic template, but issues with contamination are still present. Large-scale fabrication can be accomplished with relative ease via industrial ALD equipment and furnaces. Porous particle synthesis utilizing natural, organic templates and ALD technology offers potential for the development of economic and efficient catalytic materials.

## Future Work

In order to maximize the quality and quantity of  $Al_2O_3$  particles, as well as the surface area per unit mass, the following factors will need to be optimized:

- 1) Coating thickness applied using ALD
- 2) Quality control to avoid salt contamination
- 3) Particle distribution during the burnoff process

In addition to these factors, other species (Figure 6) of available pollen will be inorganically reproduced in an attempt to determine the species with the maximum surface area.

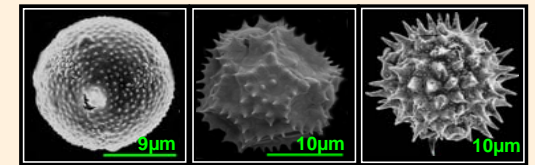


Figure 6: SEM images of other forms of pollen particles available for experimentation