Engineering High Explosives Performance by Controlling Cavities Structure

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Red Raider

Introduction

1. Theories for explosives ignition

a. Hot spot theory[1]

The heat produced from the small volume is faster than heat is being transferred to the adjacent material. The small area was heated up and temperature increased. An accelerating and self-sustaining reaction has been started. (Figure 1).

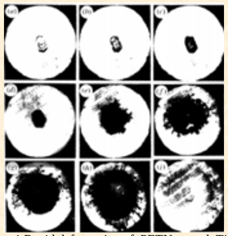


Figure 1 Rapid deformation of PETN crystal. Time of the frames: a)0, b) 7 μs, c)14 μs, d)28 μs, e)175 μs, f) 315 μs, g)350 μs, h)385 μs, i)441 μs.

b. Shock wave initiation[2]

Explosives can be detonated with a shock wave. When a shock wave enters the explosive, the material is compressed and heated, which initiates the reaction (Figure 2).

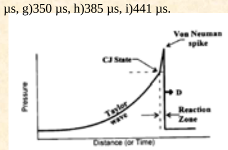


Figure 2 Structure of a detonation wave.

c. Cavities collapse under shock[3]

The cavities collapse ignition could be jet-impact and hot-gas ignition mechanisms (Figure 3), which is dependent on void shapes and sizes.

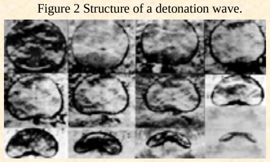
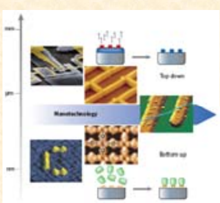


Figure 3 Cavities collapse under shock wave

2. Two approaches to control the structures of materials[4]

a. Top-down fabrication: lithography, writing or stamping;

b. Bottom–up technique: makes use of self-processes for ordering of supramolecular or solid-state architectures.



Motivation

1. Finding a feasible method to pattern micro/nano structure of organic energetic materials.
2. Patterning explosives will be used to tailor explosive output performance. Scale up of this technique will lead to engineered energetic materials where initiation and performance can be controlled through the lithographically defined microstructure.

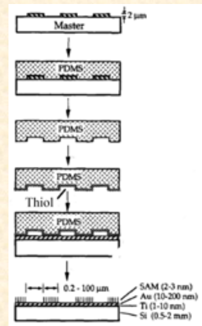
1. Field, J. E. *et al* Phil. Trans. R. Lond. A 339, 269, 1992. 2. Cooper P. W. *et al*. Introduction to the technology of explosive. Wiley-VCH Inc.1996; 3. Bourne N. K. *et al*. Proc. R. Soc. Lond. A 459, 1851, 2003. 4. Barth J.V. Nature, 437,671,2005.

Methodology

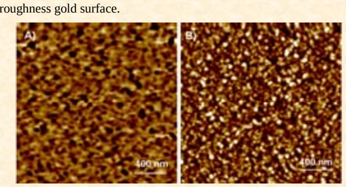
1. Substrates and pattern preparation

The gold film, prepared with the template stripping gold method, has very small RMS roughness. The patterns were prepared with 16-Mercaptohexadecanoic acid (MHA) self assembled monolayer (SAM) by microcontact printing (μCP) technique. Pentaerythritol tetranitrate (PETN) patterns were formed by spin coating PETN acetone solution on the films at 1000 rpm for 45s.

The procedure of template stripping gold method to prepare low roughness gold surface.



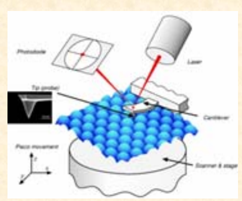
Schematic illustration of the microcontact printing process.



AFM images of two different Au surfaces. The RMS roughness of the A) Gold-striping method surface 1.8 nm, and B) the thermal evaporating surface 3.8 nm.

2. Surface characterization

The film's surface was characterized by the NanoScope IIIa tapping mode AFM, and the AM-Scope optical Microscopy.

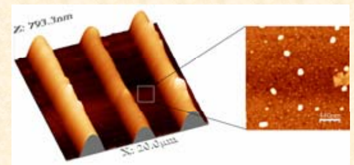


The information was gathered by "feeling" the surface with a mechanical probe which has small radius around 10 nm.

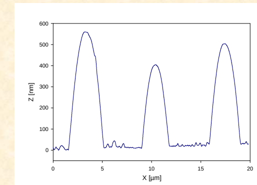
Schematic illustration of AFM.

Results and Discussion

1. Pattern formation on MHA SAM surface

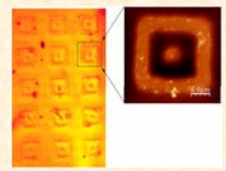


PETN formed on the patterned surface, PETN on Au surface of the pattern gaps.

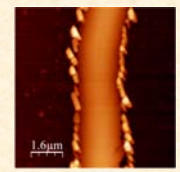


Section analysis of the pattern the pattern height can reach micrometers.

2. Complex pattern formation on MHA SAM surface



Square patterns formed on the MHA SAM.



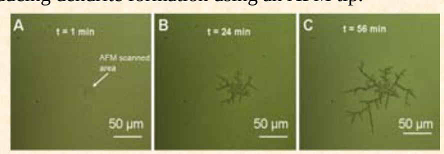
Line patterns formed on Au surface with 1-decanethiol SAM pattern, crystals grains formed on the pattern edge.

3. Hydrophobic SAMs were used to the patterns formation.

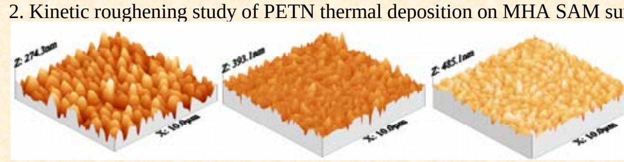
Hydrophobic -thiol 1-decanethiol was also used to pattern preparation. Crystal grains formed on the patterns borders. Comparing the pattern formation on two SAMs, a strong influence of confined geometries on the morphological features of PETN pattern growth by predefined different surface chemistries was observed.

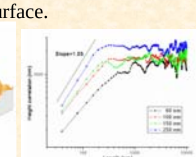
Other Advances

1. Inducing dendrite formation using an AFM tip.



2. Kinetic roughening study of PETN thermal deposition on MHA SAM surface.





3. PETN films morphology changes with deposition flux. Dendrites or facet crystal formation.

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