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Materials Letters 61 (2007) 284–287
materials letters
www.elsevier.com/locate/matlet

Chemical bath deposition of cadmium sulphide on silicon nitride: Influence of surface treatment on film growth

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Received 6 July 2005; accepted 9 April 2006
Available online 27 June 2006

Abstract

Nanoparticulate cadmium sulphide was grown by a chemical bath method on PECVD silicon nitride with various surface treatments. It was found that the packing density of the film increased in the order: untreated surface < mercaptopropyl-derivatised surface < ultra-thin (discontinuous) gold- or platinum-treated surface. This behaviour was rationalised by assuming that surface concentrations of Cd^{2+} or S^{2-} could be increased over the bulk values by producing a surface with 'soft base' or 'soft acid' chemistry, respectively.

Nanoparticle diameters were larger with ultra-thin platinum treatment than with gold. These observations may allow ordered arrays of cadmium sulphide nanoparticles to be prepared by a masking – gold seeding – bath deposition procedure.

Keywords: Cadmium sulphide; Surfaces; Semiconductors; Nanocrystals

1. Introduction

Chemical bath deposition (CBD) is a low-cost and simple technique for producing thin films of many compound semiconductors. We have previously reported a procedure for deposition of continuous, conductive cadmium sulphide on substrates such as glass [1]. Our procedure uses a mildly acidic bath, which makes it possible to pattern the CdS by photolithography using industry-standard alkali-soluble photoresists. However, we found that using the same technique with PECVD silicon nitride substrates initially yielded films consisting of isolated nanocrystals of CdS. This brief communication reports the effect of surface treatments on the particle size and packing density of CdS deposited on silicon nitride, and suggests a novel route to forming ordered arrays of CdS nanoparticles.

2. Experimental

2.1. Substrate surface treatments

Substrates were cut from silicon wafers with 500 nm silicon nitride deposited by PECVD (IDB Technology Ltd., UK). Several different substrate surfaces were generated.

(a) Silanol/silylamine rich. Substrates were cleaned by heating for 5 min in a 1:2:10 v/v mixture of concentrated ammonia solution, 50% hydrogen peroxide, and deionised water at 70 °C, then thoroughly rinsed in deionised water, and finally dried in a stream of nitrogen.
(b) Mercapto-derivatised. Substrates prepared as in (a) were heated at 180 °C in air for 10 min to remove surface water. They were then maintained at 180 °C for 10 min in the presence of 3-mercaptopropyltrimethoxysilane vapour (Sigma-Aldrich), and finally cured in air at 110 °C for 30 min.
(c) Alkyl-derivatised. As (b), but using hexadecyltrimethoxysilane (Sigma-Aldrich).

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0167-577X/$ - see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.matlet.2006.04.119

(d) Ultra-thin gold. Vacuum evaporation was used to deposit 0.2–1.0 nm of gold directly onto the substrates with no barrier/adhesion layer. Deposition vacuum was better

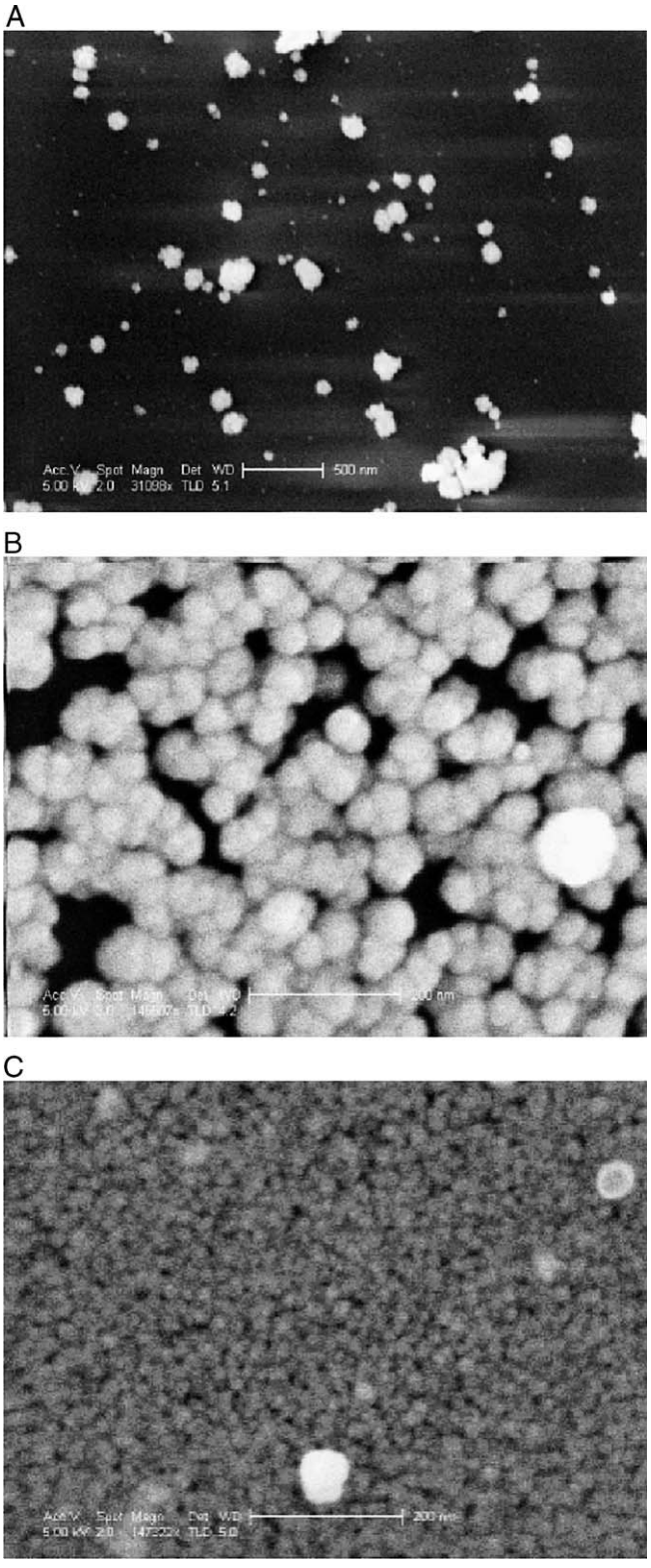

Fig. 1. Effect of silicon nitride surface treatment on CdS deposition. (a) Hydrophilic surface, scale bar = 500 nm, (b) surface modified with mercaptopropyl groups, scale bar = 200 nm, and (c) surface modified with 0.5 nm gold, scale bar = 200 nm.

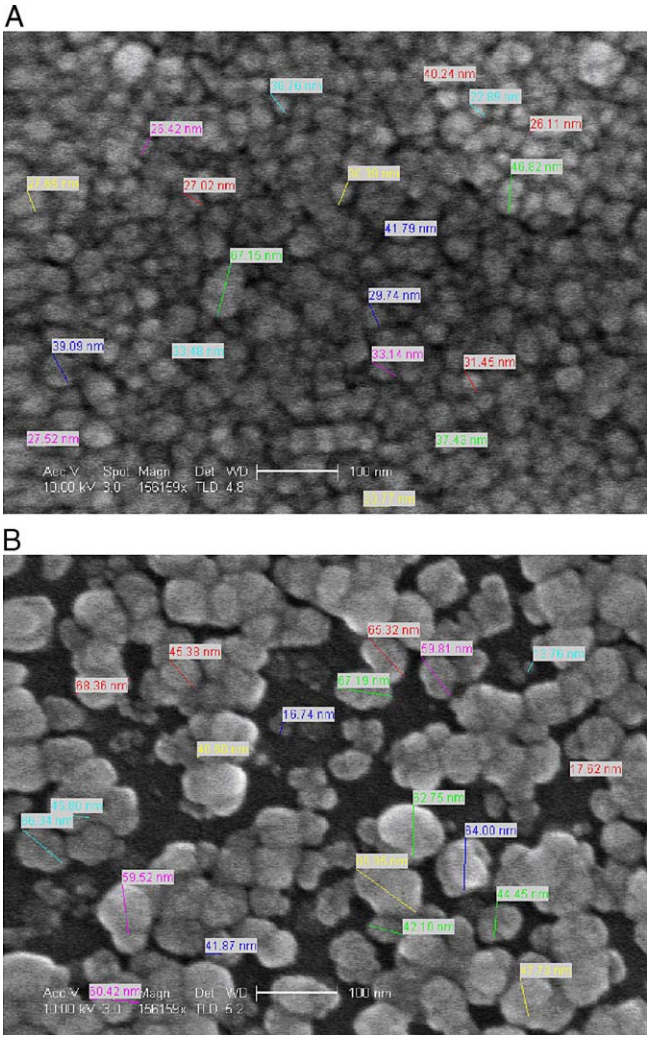

Fig. 2. CdS deposited on silicon nitride modified with 1 nm of (a) gold and (b) platinum. Scale bars = 100 nm.

than 2×10^{-6} Torr. For some samples, a suspension of polystyrene microspheres, 0.3 μ diameter, carboxylate derivatised (Interfacial Dynamics Corp.) was spread onto a clean, hydrophilic substrate and allowed to evaporate, so that the microspheres spontaneously formed ordered monolayers. After gold deposition, the microspheres were removed with 1,1,1-trichloroethylene.

(e) Ultra-thin platinum. As (d), using platinum instead of gold.

2.2. Chemical bath deposition

CBD deposition of CdS followed the method reported in [1]. A solution of cadmium chloride (0.02 M), thioacetamide (0.1 M), and urea (0.5 M) in water was prepared, and adjusted to pH 5.2–5.3 with sodium hydroxide and/or nitric acid. After placing the substrates in this solution, it was heated at 75 °C for 80 min with occasional agitation. At the end of the reaction, the substrates were rinsed thoroughly in deionised water, then in ethanol and acetone, and allowed to dry in air.