Applied Surface Science 259 (2012) 55–58

Contents lists available at SciVerse ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Sorbitol as an efficient reducing agent for laser-induced copper deposition

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ARTICLE INFO

Article history:
Received 19 February 2012
Received in revised form 11 June 2012
Accepted 25 June 2012
Available online 30 June 2012

Keywords:
Sorbitol
Reducing agent
LCLD
Laser-induced deposition
Solution
Copper
Topology

ABSTRACT

We have pioneered in revealing the fact that sorbitol may be used as an efficient reducing agent in the process of laser-induced copper deposition from solutions; in this case, it is possible to obtain copper lines much higher quality than by using conventional formalin.

1. Introduction

The technique of laser-induced chemical liquid phase deposition (LCLD) is based on the metal deposition on the substrate surface in the laser beam focal zone. The LCLD technique enables creation of high-quality small-size metal structures on the surfaces of various dielectrics and semiconductors without using any phototemplates [1].

By scanning a focused laser beam over the surface of dielectric submerged into the solution suitable for copper coating, it is possible to locally initiate the chemical reaction of metallic copper reduction according to Eq. (1) [2,3]:

$$CuL^{(n-2)-} + 2HCHO + 4OH^- \rightarrow Cu^0 + L^{n-} + H_2 + 2HCOO^- + 2H_2O \quad (1)$$

where L is one or several ligands (sequestering agent).

The drawback of the conventional technique involving formaldehyde as an LCLD reducer is that the process is accompanied by intense gas formation.We have previously established [2] that this gas-formation is due to the decomposition of the formaldehyde and its reaction products.

The gas bubbles defocus the laser beam and, hence, make the copper sediments porous (Fig. 1) and discontinuous [2,3]. Based on the results of papers [4,5], we can conclude that electric resistivity of such sediments is higher than that of pure copper by 2.5–4 orders of magnitude [6].

All this makes it relevant to search for other reducing agents that are stable at LCLD. These reducing agents, in particular, may be polyols, which are now widely used instead of formaldehyde for conventional chemical copper plating. Our study of these reducing agents for the laser-induced copper plating has also shown promising development in this direction. At the same time surprisingly good structure of the copper deposit and its electrical properties were obtained when we replaced the traditional formaldehyde in the reaction (1) to the sorbitol. These results are presented in this paper.

2. Material and methods

The experiments on laser-induced copper deposition from solutions were conducted by using the setup depicted in Fig. 2 [5].

The argon laser beam (1) passes through the beam splitting cube, (2) that directs a portion of the laser radiation to the CCD camera designed for optical focusing and *in situ* monitoring of metal deposition. The sample-targeted beam is focused (so as to produce a 5-μm spot at the $1/e^2$ intensity) by using a ×4 microscope objective lens, (3) at the dielectric/solution interface. Geometrically, the dielectric was irradiated "from the side of solution". The dielectric

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0169-4332/$ – see front matter © 2012 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.apsusc.2012.06.085

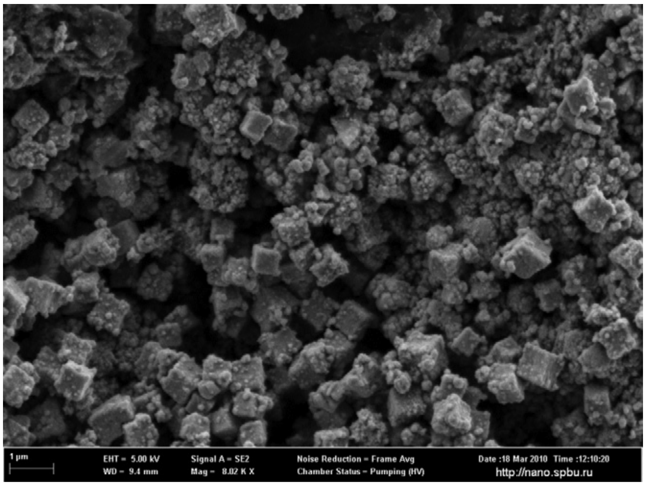

Fig. 1. A microphotograph of a copper structure deposited according to the reaction scheme (1) (with sodium potassium tartrate as a complexing agent). The microcrystal size is about 0.5 μm [3].

and electrolyte solution were placed on the motorized translation stage (7) driven by the controller (11). The operating commands from computer (10) were generated by original software. The same computer received data from the CCD-camera (9) that was used to record the deposition process in the real-time mode [5].

The copper structures were deposited by using a continuous Ar^{+} laser working in the multimode manner within the power range of 30–1000 mW. Using the optical system, the laser beam was focused

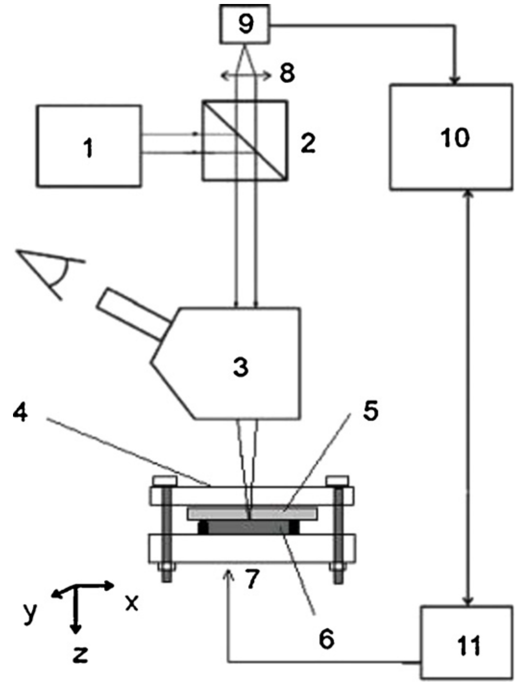

Fig. 2. Schematic diagram of the experimental setup for LCLD metal deposition. 1 – Ar+ laser, 2 – beam splitter, 3 – microscope, 4 – cuvette, 5 – transparent dielectric substrate (glass), 6 – aqueous solution for chemical metallization, 7 – 3D motorized translation stage, 8 – focusing lens, 9 – CCD camera, 10 – computer, and 11 – translation stage controller.

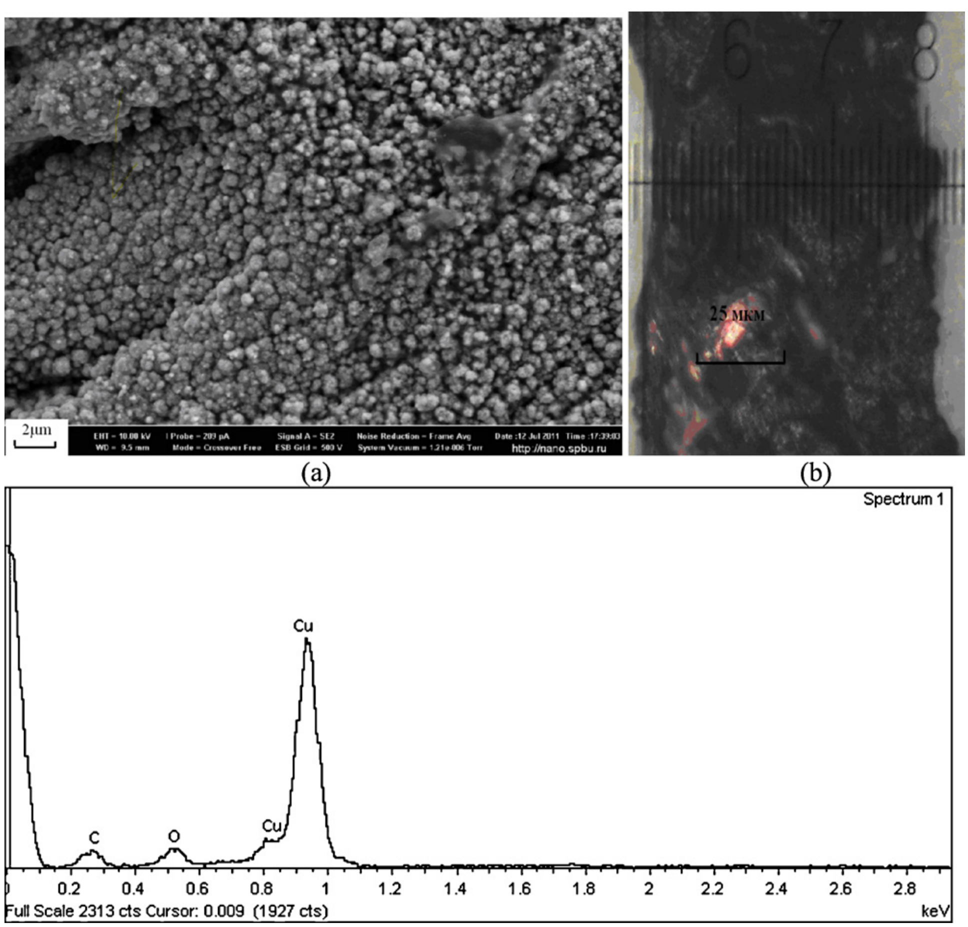

Fig. 3. SEM (a) and optical (b) microphotographs of the copper sediment made from the solution with sorbitol as a reducer (the scale rate is given in the figure). (c) Presents the copper sediment EDX-spectrum.