XTPL Approach to Print Submicron Conductive Lines on Dielectric Substrates

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ABSTRACT

The concepts of printed electronics offer a tremendous potential when brought to nanotechnology. We present a novel technology for printing submicron conductive lines at unprecedented flexibility, accuracy, and low cost. The lines with resistance down to 2 Ω/μm are formed from metallic nanoparticles (e.g., Ag or Au). The feature size of the printed structures is in the range between 100 nm to 3 μm, with the width-to-height aspect ratio close to 1. This method has been implemented in the XTPL Submicron Lab Printer.

Keywords: submicron conductive lines, nanomaterials, nanoparticle assembly

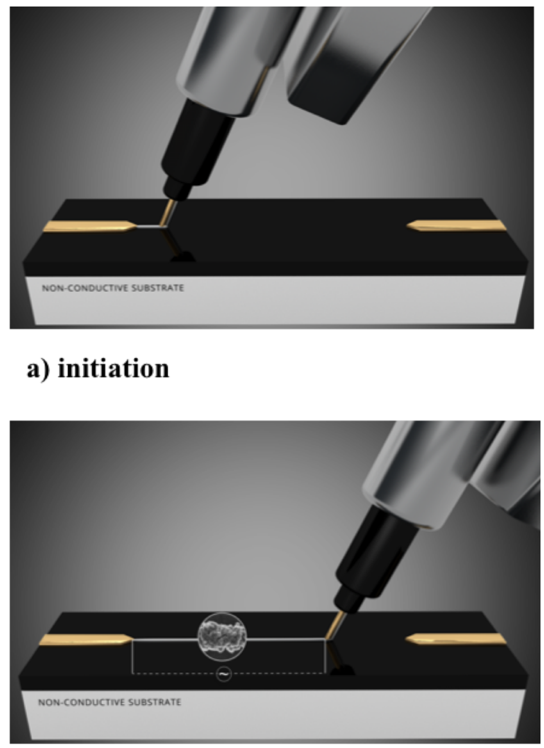
1 INTRODUCTION

The concept of printing nanomaterials paves the way for cheap and scalable fabrication of photonic devices. In this contribution we will discuss both the fundamental process of a guided assembly of nanoparticles and its implementation in the XTPL Submicron Lab Printer.

2 GUIDED ASSEMBLY OF NANOPARTICLES

Our approach [1] is based on a guided assembly of nanoparticles using the dielectrophoretic attraction [2], [3]. At first, nanoparticles are chaotically distributed in a liquid solution (ink). During the printing process, the printing head deposits the ink on a substrate and nanoparticles form conductive line under an external alternating electric field. Figure 1 shows how the line formation is guided by the moving electrode. The electric field is generated by voltage in the range of 5 to 30 V. Finally, the printing head takes in the excess ink.

During the process, the line itself becomes an extension of the electrode. Therefore, in principle, it is possible to print lines of an arbitrary length. The line properties, such as morphology and resistivity, are tuned by changing 1) parameters of the process, including the amplitude, shape, and frequency of the electrical signal; 2) physicochemical properties of the inks; 3) shape and size distribution of nanoparticles. Figure 2 a) shows SEM image of an example silver conductive line obtained using the XTPL method. The width of the line is around 1 μm.



a) initiation

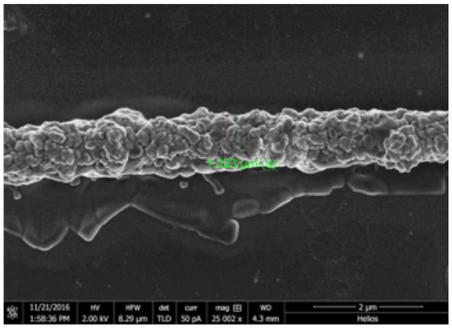
b) line formation

Figure 1 Sketch showing the main stages of the XTPL process: a) initiation and b) formation of a conductive line from nanoparticles under an external alternating electric field. (Source: XTPL SA.)

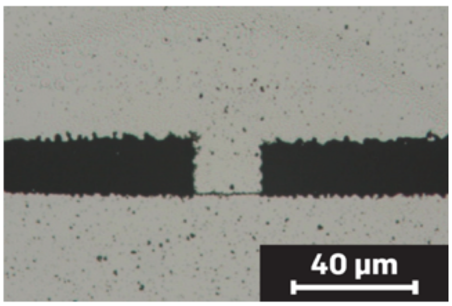
3 XTPL SUBMICRON LAB PRINTER

This technology has been already implemented in the XTPL Submicron Lab Printer. The heart of our printer is the printing head, which allows a precise application of ink. The amount of dispensed ink is extremely low, so that the ink consumption is minimal.

The printing process can be performed on any type of dielectric substrates, including glasses, flexible foils, and printed circuit boards. There are also no intrinsic limitations regarding the shape of the substrate. Finally, neither clean-room conditions nor toxic gases are required.



a)



b)

Figure 2 a) SEM image of a silver conductive line obtained using the XTPL method. The width of the line is around 1 µm. b) Possible application: artificial 20 µm wide open defect is bridged using the XTPL method. The width of the connection is around 1 µm. (Source: XTPL SA.)

4 APPLICATIONS

There are a number of possible applications of this technology, including fabricating thin transparent conductive films for solar cells, displays, touch screens etc. Another application involves functionalized nanostructures for biosensors. Finally, repairing electrical defects in integrated circuits has been successfully demonstrated, fulfilling an industrial specification regarding resistance and adhesion of the connection to the substrate. Therefore, the XTPL approach becomes an attractive alternative to existing technologies used for repairing open defects [4]. These technologies include Focus Ion Beam (FIB) and Laser Chemical Vapor Deposition (LCVD). For example, Figure 2 b) shows an artificial 20 µm wide open defect bridged using the XTPL method.

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