

Inkjet printing of nanosized silver colloids

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Received 27 April 2005, in final form 15 August 2005

Published 2 September 2005

Online at stacks.iop.org/Nano/16/2436

Abstract

A water-based conducting ink, composed of well dispersed nano-silver particles, has been successfully inkjet printed using an ordinary commercial printer. The silver colloids with diameter around 50 nm were dispersed in a water and diethylene glycol cosolvent system. The 25 wt% silver ink had a viscosity of about 7.4 cP and surface tension of 33.5 dyn cm⁻¹ at 20 °C, which is appropriate for printing jobs. Continuous and smooth lines of 130 µm width could be printed on ordinary glass substrates using an Epson R210 printer. After baking at 260 °C for 3 min, these lines exhibited a resistivity of 1.6×10^{-3} Ω cm, which could serve as conducting lines for electronic applications.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

In the electronic industry, fabrication of conductive lines (circuit) is vital and inevitable. Traditionally, for example, electroplating and etching processes accompanied by lithography technology are widely adopted in the printing circuit board (PCB) industry for manufacturing its circuits. However, this method is not only time consuming but also very complicated, because many steps are required to construct one layer of circuit. Moreover, the conventional electroplating and etching processes also produce large quantities of waste water. For these reasons, the development of convenient and fast processing techniques to fabricate conductive lines has attracted more and more attention in recent years.

One of the most promising alternatives is the ink-jet printing technology, by which the conductive lines can be drawn (i.e. printed) onto the substrate in one step. There are two important components of the ink-jet printing technology: one is the mechanical system, i.e. the printer, and the other is the conductive material, i.e. the ink. Studies focused on the former item discussed the formation of droplets, accurate control of dropping location, jetting parameters, etc [1–5]. On the research of conductive ink, several materials were studied including molten metal, conductive polymer, and metallic nanoparticle suspension [6]. Among these, metallic nanoparticle suspension gained significant interest in recent years because it can be operated at room

temperature [7] as compared to the molten metal, and also has a better performance in terms of conductivity than conductive polymers on the other hand.

Viscosity and surface tension are the two most important properties of general inks [8]. Size, dispersion and stability of metallic nanoparticles are also crucial for the conductive ink system, because the nozzle of the printer would be clogged with larger particles or due to the aggregation of nanoparticles. In addition, the physical properties of metallic nanoparticles undoubtedly affect the performance of the product to a great extent. Due to their high conductivity and thermal stability, gold and silver nanoparticle suspensions were widely used in the studies of conductive ink. Some operating parameters in these studies are listed in table 1 [9–14] for comparison. In the work by Fuller *et al* in 2002 [9], Ag nanoparticles suspended in α -terpineol were printed by the piezo-driven ink-jet printer onto a heated substrate at 100–300 °C. After sintering at 500 °C for 10 min, the fabricated lines showed a resistivity of approximately 3 µΩ cm, about twice that of bulk silver (1.51 µΩ cm). However, in this case α -terpineol was used as the solvent and it may cause the problem of volatile organic compounds (VOCs) in realistic industrial applications. In the work of Bieri *et al* in 2004 [12], Au nanoparticles suspended in toluene were used. Conductive ink droplets were generated by the piezo-driven ink-jet printer and deposited onto a moving substrate to form continuous lines. Then focused laser irradiation was utilized to evaporate the solvent and sinter these Au nanoparticles. The result showed that micro-lines

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Anh Nguyen,2022-10-26 Smart Multifunctional Nano inks Fundamentals and Emerging Applications covers nano inks and how they can be used in inkjet printers for printing complex circuitry on flexible substrates or as a paste for 3D printers Microstructures can be 3D printed using nano inks in a combination of high resolution plasma printing and subsequent rotogravure printing In addition smart multifunctional nano inks are not only required for the electronic but also in other applications such as for secure inks for currency and in immigration documents This book focuses on fundamental design concepts promising applications and future challenges of nano inks in various areas such as optoelectronics energy security and biomedical fields The current challenge for the successful industrial application of nano inks is in the preparation of a stable dispersion of advanced materials for nano inks The functionalization synthesizing and theoretical modeling provide the solution for most of the current issues but there are still remaining challenges which are covered in this comprehensive resource Outlines the major nanomaterials used in the manufacture of smart nano inks Provides information on the major industrial applications of nano inks Assesses the major challenges of using nano inks in a cost effective way and on an industrial scale

Handbook of Industrial Chemistry and Biotechnology James A. Kent,2013-01-13 Substantially revising and updating the classic reference in the field this handbook offers a valuable overview and myriad details on current chemical processes products and practices No other source offers as much data on the chemistry engineering economics and infrastructure of the industry The Handbook serves a spectrum of individuals from those who are directly involved in the chemical industry to others in related industries and activities It provides not only the underlying science and technology for important industry sectors but also broad coverage of critical supporting topics Industrial processes and products can be much enhanced through observing the tenets and applying the methodologies found in chapters on Green Engineering and Chemistry specifically biomass conversion Practical Catalysis and Environmental Measurements as well as expanded treatment of Safety chemistry plant security and Emergency Preparedness Understanding these factors allows them to be part of the total process and helps achieve optimum results in for example process development review and modification Important topics in the energy field namely nuclear coal natural gas and petroleum are covered in individual chapters Other new chapters include energy conversion energy storage emerging nanoscience and technology Updated sections include more material on biomass conversion as well as three chapters covering biotechnology topics namely Industrial Biotechnology Industrial Enzymes and Industrial Production of Therapeutic Proteins

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PREFACE THE Author of this very practical treatise on Scotch Loch Fishing desires clearly that it may be of use to all who had it He does not pretend to have written anything new but to have attempted to put what he has to say in as readable a form as possible Everything in the way of the history and habits of fish has been studiously avoided and technicalities have been used as sparingly as possible The writing of this book has afforded him pleasure in his leisure moments and that pleasure would be much increased if he knew that the perusal of it would create any bond of sympathy between himself and the angling community in general This section is interleaved with blank sheets for the readers notes The Author need hardly say that any suggestions addressed to the case of the publishers will meet with consideration in a future edition We do not pretend to write or enlarge upon a new subject Much has been said and written and well said and written too on the art of fishing but loch fishing has been rather looked upon as a second rate performance and to dispel this idea is one of the objects for which this present treatise has been written Far be it from us to say anything against fishing lawfully practised in any form but many pent up in our large towns will bear us out when we say that on the whole a days loch fishing is the most convenient One great matter is that the loch fisher is dependent on nothing but enough wind to curl the water and on a large loch it is very seldom that a dead calm prevails all day and can make his arrangements for a day weeks beforehand whereas the stream fisher is dependent for a good take on the state of the water and however pleasant and easy it may be for one living near the banks of a good trout stream or river it is quite another matter to arrange for a days river fishing if one is looking forward to a holiday at a date some weeks ahead Providence may favour the expectant angler with a good day and the water in order but experience has taught most of us that the good days are in the minority and that as is the case with our rapid running streams such as many of our northern streams are the water is either too large or too small unless as previously remarked you live near at hand and can catch it at its best A common belief in regard to loch fishing is that the tyro and the experienced angler have nearly the same chance in fishing the one from the stern and the other from the bow of the same boat Of all the absurd beliefs as to loch fishing this is one of the most absurd Try it Give the tyro either end of the boat he likes give him a cast of ally flies he may fancy or even a cast similar to those which a crack may be using and if he catches one for every three the other has he may consider himself very lucky Of course there are lochs where the

fish are not abundant and a beginner may come across as many as an older fisher but we speak of lochs where there are fish to be caught and where each has a fair chance Again it is said that the boatman has as much to do with catching trout in a loch as the angler Well we dont deny that In an untried loch it is necessary to have the guidance of a good boatman but the same argument holds good as to stream fishing

The Theory and Application of Colloidal Behavior Robert Herman Bogue,1924 **Silver Colloids** Ronald J. Gibbs,1999 **The Colloidal Salts** Harry Boyer Weiser,1928 **Kolloides Silber Und Die Photohaloide** Hinricus Lüppo-Cramer,Mathew Carey Lea,2023-07-18

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au travers de l appareil du parti nazi du gauleiter au blockleiter la gestapo dispose en allemagne de dizaines de milliers d oreilles et d yeux attentifs mais la gestapo proprement dite n a pas développé un encadrement lourd de la population en raison de l encadrement par le parti mais aussi des nombreuses lettres de dénonciation que ses services reçoivent tous les jours à cologne en 1942 on compte 69 membres de la gestapo pour 750 000 habitants si l

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