Corrosion Science 104 (2016) 1–8

Contents lists available at ScienceDirect

Corrosion Science

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

Lateral resolution in scanning Kelvin probe microscopy

Mariusz Wicinski [a,b], Wolfgang Burgstaller [c], Achim Walter Hassel [a,c,*]

[a] Institute for Chemical Technology of Inorganic Materials, Johannes Kepler University, Altenberger Str. 69, 4040 Linz, Austria
[b] Wicinski–Wicinski GbR, Kreuzstr. 7, 42277 Wuppertal, Germany
[c] Christian Doppler Laboratory for Combinatorial Oxide Chemistry, at the Institute for Chemical Technology of Inorganic Materials, Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz, Austria

ARTICLE INFO

Article history:
Received 18 April 2015
Received in revised form 5 September 2015
Accepted 11 September 2015
Available online 15 September 2015

Keywords:
B. AFM
A. Metal coatings
A. Aluminium
A. Copper
B. Modelling studies

ABSTRACT

The lateral resolution of a scanning Kelvin probe (SKP) is a key parameter for investigating microstructures. It depends on two main device parameters, the tip diameter and the tip sample distance. Variation of them affects physical parameters like stray capacitance and signal intensity. A model sample with a sharp border between two materials of different work function (Al/Cu) has been produced. Line-scans perpendicular to the Al–Cu edge show the influence of tip diameters and tip-sample gaps. A mathematical expression for the maximum lateral resolution was derived by the method of images. These calculations are in good agreement with systematic measurements.

© 2015 Published by Elsevier Ltd.

1. Introduction

Local surface potential measurements gain more and more importance in various fields of technical applications. In semiconductor industry chemical surface contamination as well as metal impurities in silicon wafers lead to changes in the electrical character of the sample. Therefore techniques to detect and characterize such defects are highly interesting [1]. Organic light emitting devices are a powerful technology for actual display applications. Finding suitable anode materials with reduced energy barrier between the involved Fermi levels is of importance to improve the performance [2]. Continuous developments in the field of photovoltaic cells are inalienable for future energy technology [3]. The study of corrosion processes on metal surfaces [4] is an ongoing research and very important e.g. for the automotive industry. Therefore investigations of various processes concerning delamination of polymeric coatings [5–7] and thin layers of electrolyte on a metal [8–12] have extensively been done.

The above mentioned topics have one together: all of them can somehow be investigated by means of the scanning Kelvin probe (SKP), which is a suitable device to measure the surface potential distribution of a conducting or semi-conducting sample. One main advantage is the possibility to measure without contact and non-destructively the fluctuations in the surface potential by probing the outermost layer of a material. The technique was first described by Lord Kelvin [13] and consequently improved [14–17]. The functional principle is as follows: if two different conducting materials are brought in close vicinity to each other and connected via an external circuit, their Fermi levels equalize. This forms an electron flow from the metal with the higher work function to the one with the lower work function leading to oppositely charged surfaces. The formed Volta potential gradient is called contact potential difference (CPD). The setup can be seen as a parallel plate capacitor in which the electric field formed between the two metals compensates for their difference in work function. Vibrating one of the plates (the probe) leads to charging and discharging of the capacitor with the frequency of the vibration. For the nulling SKP method the resulting current becomes zero as soon as an external voltage (backing potential, V_b) is applied which is varied fully automatically by the system until a zero field state is reached. The backing potential is equal to the CPD. The SKP system used in this work applies the amplitude modulation method for the CPD estimation [8]. For further information regarding the functional principle, refer to the literature [18–21].

The need for higher lateral resolution for the investigation of surface phenomena, which occur in the sub-micron scale, led to the development of the high-resolution scanning Kelvin probe microscopy (SKPFM) [22]. However, there are still some drawbacks

* Corresponding author at: Institute for Chemical Technology of Inorganic Materials, Johannes Kepler University, Altenberger Str. 69, 4040 Linz, Austria. Fax: +43 732 2468 8905.
E-mail address: achimwalter.hassel@jku.at (A.W. Hassel).

http://dx.doi.org/10.1016/j.corsci.2015.09.008
0010-938X/© 2015 Published by Elsevier Ltd.

for these systems, like the increased sensitivity to signal artefacts [23].

Therefore the conventional SKP systems have still importance and further investigations regarding the device parameters are needed. On the one hand the SKP tip diameter plays an important role, but also the distance between the tip and the measured sample surface is of interest. Published studies [24] show a distinct relationship between tip-sample distance and tip diameter for tip diameters <140 μm. In this paper a detailed practical and theoretical study according to physical influences to SKP tip diameter and sample to tip distance is performed.

Two issues related to the lateral resolution of the SKP technique [24] have been considered in this work:

First, the theoretical background of the electrostatic calculation based on the method of images is applied to estimate the influence of the distance between a probe of negligible size (point probe) and the specimen on a lateral SKP resolution. The results from the "point-probe" calculations are used to define the limiting parameters for the lateral resolution, which are the half width of charge density and the width of SKP response. These parameters are finally used to estimate the ability of the real Kelvin probe to resolve the surface potential distribution on the real specimen.

Second, the point-probe theory for limiting SKP resolution is combined with the semi empirical relationship between probe diameters, a probe-specimen distance, and a lateral response width for plane cylindrical probes in order to evaluate the experimental results. Finally the influence of the fringing fields on the SKP resolution is discussed and its contribution for the total Kelvin current is quantified.

2. Material and methods

2.1. Specimen preparation

For the investigation of the lateral resolution of the SKP, a sharp border between two different materials has to be found. The materials should have a number of requirements such as good electrical conductivity, clean and flat surfaces and a reasonable difference in work function. Therefore a combination of metallic Aluminium and metallic Copper has been chosen, satisfying the above mentioned preconditions, especially a gap in work function of about 0.880 eV [25]. To provide a clean and flat surface, a piece (15 mm × 15 mm × 3 mm) of high purity Cu (>99.99 at.%) was ground using SiC grinding paper with grain sizes down to 4000, followed by polishing with SiC paste (1 μm) and cleaning ultrasonically in ethanol. Al was thermally evaporated on the pristine Cu surface covering half of the Cu-specimen with a glass slide to prevent deposition on a defined region of the specimen only. 40 mg Al (99.9 at.%) were placed on a resistively heated tungsten wire and the chamber was pumped down to a deposition pressure of 6×10^{-5} kPa (rotary vane pump and oil diffusion pump). By applying 2 V at 20 A for 30 s the aluminium is evaporated and deposited on the Cu substrate forming a 370 nm thick Al-layer. The distance between source and substrate was 8 cm. Due to the small size of the sample the naturally formed thickness gradient resulting from the cosine law distribution in thermal deposition processes [26], can be neglected. A photograph of the specimen with the zoomed section between the aluminium and the copper is given in Fig. 1.

To prove the smoothness of the surface Atomic force microscopic (AFM) topography scans were performed using a nanosurf Easyscan AFM (Nanosurf AG, Liestal, Switzerland) operating in contact mode with a silicon cantilever (ContAl-G aluminium reflex coating, tip radius <10 nm, tip height 17 μm, force constant 0.2 N m^{-1}).

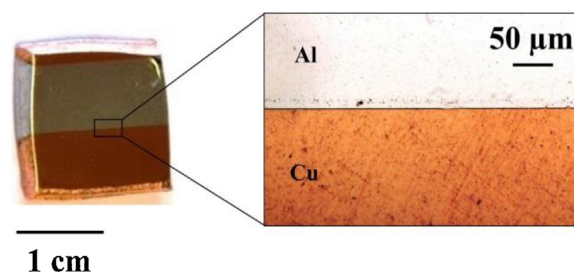

Fig. 1. Photograph of the Al–Cu specimen with the zoomed section between the two materials (20× magnification).

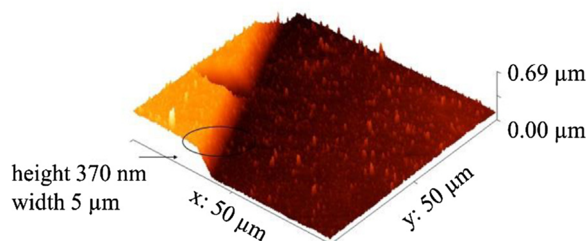

Fig. 2. AFM image of the produced Al–Cu step showing a step height of about 370 nm and a step width of 5 μm.

The thickness of the Al layer as well as the step quality (between Al and Cu) was measured by AFM. This was done by evaluating the *z*-shift obtained while scanning across the Al–Cu edge. The results of the AFM measurement are shown in Fig. 2.

It is important to provide a step size smaller than the lateral resolution of the SKP and also a step height which does not influence the SKP signal and cannot be detected by the SKP automatic height control. All these criteria are fulfilled by this specimen.

2.2. Scanning Kelvin probe measurements

The measurements have been performed in an in house developed SKP. The scanning Kelvin probe instrument itself (Wicinski–Wicinski GbR) was assembled into a completely closed stainless steel chamber with an ITO coated glass view port. The SKP needle is attached to a permanent magnet and vibrated at a frequency of 1 kHz, the AC baking potential frequency is 10 Hz. The Kelvin probe potential is a modulated signal which can be used to calculate a scaling factor k before starting the measurement. This factor is kept constant throughout the experiment defining a certain distance between the probe tip and the sample surface. Automatic height control is achieved by adding a DC voltage to the AC coil voltage. As soon as the DC voltage exceeds a pre-set limit, the probe-sample distance is adjusted by a stepper positioner in z-direction. A sample stage driven by x-axis and y-axis micro-stepper positioners allows a self-controlled positioning and scanning of a defined area. A custom made air condition system opens up the possibility to fully automatically control the atmosphere (humidity and gas composition) within the chamber. The ability to keep the atmosphere constant during the measurements is of special importance. Several studies have shown the influence of the humidity on the electron work function and thus on the CPD values due to variations in the surface dipole layers [27] or changes in the corrosion potentials between the metal and a thin electrolyte layer on the surface [28,29].

The Al–Cu specimen was mounted on a stainless steel sample holder using Cu clamps to provide good electrical conductivity. Measurements using plane ended CrNi probe-tips with different tip diameters D of 33 μm, 154 μm, 242 μm, and 330 μm have been performed. All measurements were carried out at a relative humidity

Download English Version:

https://daneshyari.com/en/article/7894684

Download Persian Version:

https://daneshyari.com/article/7894684

Daneshyari.com