

RESEARCH ARTICLE | JULY 01 1976

## Piezoelectric driven Kelvin probe for contact potential difference studies

K. Besocke; S. Berger



*Rev. Sci. Instrum.* 47, 840–842 (1976)

<https://doi.org/10.1063/1.1134750>



### Articles You May Be Interested In

Effect of adsorbed species on the surface potential of AgBr

*J. Appl. Phys.* (June 1982)

ESR and ENDOR studies of irradiated cysteine HCl: Decarboxylation

*J. Chem. Phys.* (December 1981)

Paramagnetic Catalysis of the Ortho—Parahydrogen Conversion

*J. Chem. Phys.* (January 1967)



Special Topics Open  
for Submissions

[Learn More](#)

# Piezoelectric driven Kelvin probe for contact potential difference studies

K. Besocke and S. Berger

*Institut für Grenzflächenforschung und Vakuumphysik, Kernforschungsanlage Jülich GmbH, 517 Jülich, Germany*

(Received 20 February 1976; in final form, 29 March 1976)

A convenient piezoelectric driven Kelvin probe for the measurement of work function changes is described. The probe has a simple construction, is small, bakeable, and can be mounted on any 35-mm-i.d. UHV flange. As the piezoelectric device is inside the vacuum chamber, only one electrical feedthrough is needed for operating the probe. The distance between reference electrode and sample can be varied within  $\pm 0.5$  mm simply by applying a dc voltage to the piezoelectric device in addition to the ac oscillator-driving voltage, not requiring any mechanical driving and feedthrough provisions. The probe was tested studying the adsorption of  $O_2$  on Pt(111). The sensitivity for contact potential measurements is better than 0.1 meV at a response time of 10 sec.

Work function (wf) measurements are not only one of the oldest but also one of the most sensitive methods used in surface physics. Adsorption processes as well as changes in the surface structure cause pronounced wf changes. The literature on this subject is abundant. Various techniques for wf studies such as photoelectric, thermionic, or contact potential difference (CPD) methods, are being applied. Measuring the CPD between a sample and a reference electrode (Kelvin method)<sup>1</sup> has the advantage of being one of very few nondestructive methods in surface analysis, unlike many methods using particle or light beams. This is one reason why CPD measurements are widely used in modern surface physics, not only as the main test subject but also as a supplementary tool to all kinds of surface studies.

The ac Kelvin probe first developed by Zisman<sup>2</sup> was in the course of time improved and refined and suited for special purposes.<sup>3-7</sup> A general description of this method, considering problems such as stray fields, reference electrodes, and noise, is given by Surplice and D'Arcy.<sup>8</sup>

The reason for adding a new approach to this old technique is to offer a highly sensitive and easy-to-handle probe which does not require any complicated mechanical driving and feedthrough provisions and can be installed in any standard UHV system requiring only a 35-mm-i.d. flange with one electrical feedthrough.

The principle of operation is shown in Fig. 1. The CPD is measured between the oscillating reference electrode R and the sample S. The reference electrode is deposited or mounted on an oscillator reed V. Material and shape of the reference electrode can be chosen to suit the special experimental needs. In order to achieve a high oscillator frequency the reed material should have a high  $E/\rho$  ratio where  $E$  is Young's modulus and  $\rho$  the density. Materials like W, Mo, Ti, Be or mica are favorable. We used a reed of poly-

crystalline Mo 26 mm long, 1.5 mm wide and 0.1 mm thick. One end of this reed  $2 \times 1.5$  mm served as the reference electrode. On the other end a foil of piezoelectric ceramic (type PTZ H42, 0.1 mm thick, supplied by Siemens AG, München) with vapor-deposited Au contacts on both faces is fastened to the last section of the oscillator reed. As a cement a leak seal compound (Vacuum Generators) or a 2-component varnish<sup>9</sup> showed satisfactory results. The oscillator device, consisting of reference electrode, reed, and piezoelectric driver, is clamped in a holder and mounted in the desired position on a 35-mm-i.d. UHV flange equipped with a feedthrough for the electric connection of the piezoelectric driver. Before operation the piezoelectric foil had to be polarized by a dc voltage pulse above 100 V. The oscillator device was then cleaned ultrasonically and baked at 200°C for 3 h. After installation in the UHV chamber and a routine bakeout at 200°C for 24 h, the system was pumped down to  $4 \times 10^{-11}$  Torr. No contamination arising from cement and piezoelectric ceramic could be detected in the residual gas mass spectrum.

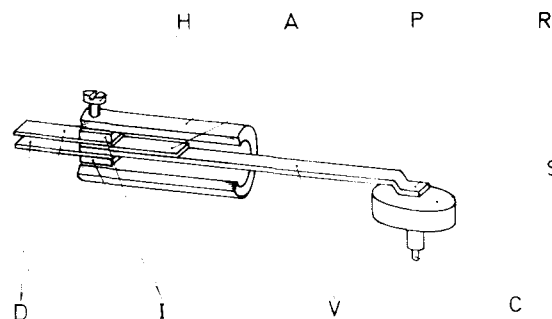


FIG. 1. Piezoceramic driven Kelvin probe. R—Reference electrode; S—specimen; C—connection to amplifier; V—vibrating reed; P—piezoelectric foil; I—insulators; H—holding screw; A—shielding; D—electric connections.

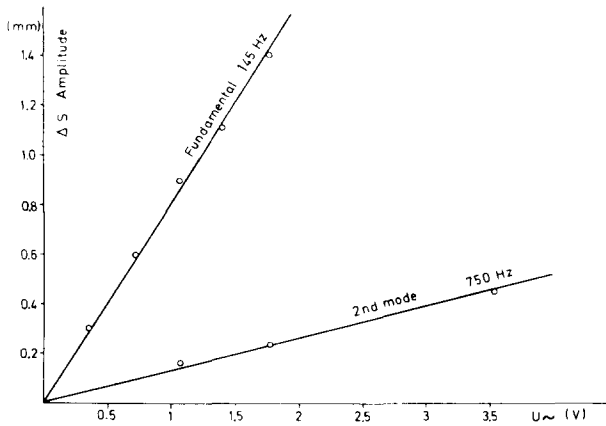


FIG. 2. Oscillation amplitude as function of the applied ac driving voltage.

Applying a voltage to the piezoelectric driver causes the foil to shorten or to dilate depending on the voltage polarity bending the whole oscillator device.

Contact potential measurements were made operating the oscillator device in the fundamental or in the 2nd resonance mode. In our case, with a Mo reed of 26 mm length and 0.1 mm thickness, the resonance frequency was 145 and 750 Hz, respectively. The ratio of the fundamental to the 2nd resonance mode is close to the theoretically expected value.

Figure 2 shows the oscillator amplitude Δs for the tested device as a function of the applied ac voltage in the fundamental and in the 2nd resonance mode. In general an oscillation amplitude of 0.2 mm is sufficient for contact potential measurements. The corresponding ac driving voltage of only 0.3 and 1.5 V, respectively, at currents below 1 μA makes it easy to keep all stray fields under control by applying simple shielding. Adding a dc component to the ac driving voltage causes the device to bend without noticeable changes in the resonance amplitude. The magnitude of the dc voltage can thus be used to vary the distance between reference electrode and sample.

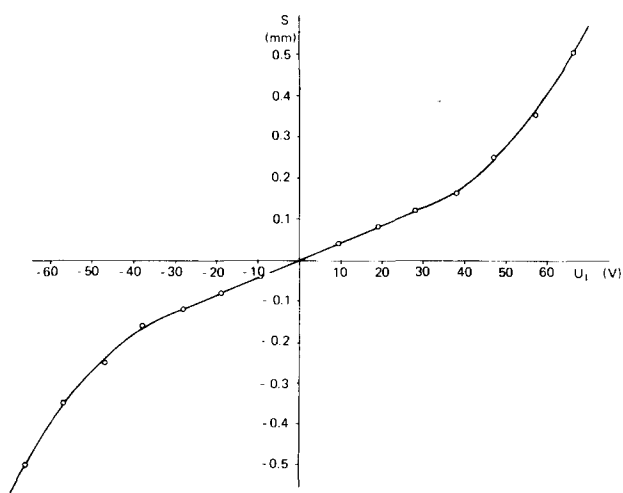


FIG. 3. Distance variation as function of the applied dc voltage.

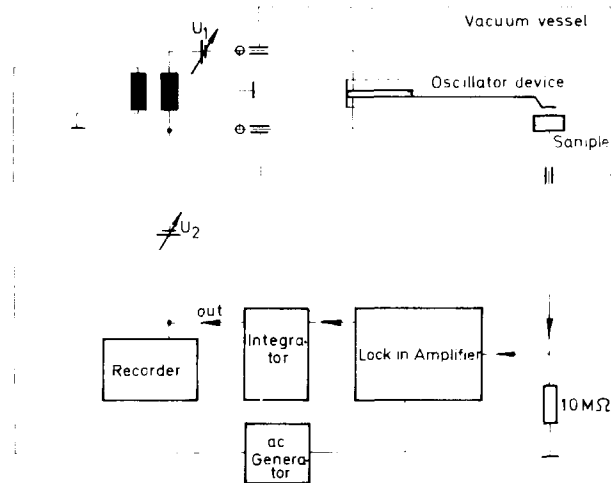


FIG. 4. Schematic test circuit of the Kelvin probe.

Figure 3 shows the distance variation as a function of the applied dc voltage. In the applicable voltage range of ±70 V the mean distance of the reference electrode can be adjusted very precisely within the range of ±0.5 mm, making a mechanical feedthrough for device manipulation unnecessary in most cases. Using electronic feedback techniques similar to those of Hölzl and Schrammen,<sup>5</sup> the mean distance between sample and reference electrode can be controlled automatically.

Figure 4 shows the electronic test circuit. The ac sine wave signal from a generator is coupled via a transformer to the piezoelectric device. U<sub>1</sub> controls the mean distance between reference electrode and sample. U<sub>2</sub> is for simulation and compensation of work function changes. The reference electrode is connected to the feedback loop of the lock-in amplifier via an integrator for a continuous nulling of the ac signal. The absolute work function changes are registered directly on a recorder. To avoid amplitude variations caused by changes of the resonance frequency, a self-maintaining oscillator circuit which keeps the reed in its resonance state may be applied.<sup>10</sup> The sensitivity was in our case limited by poor shielding of the sample

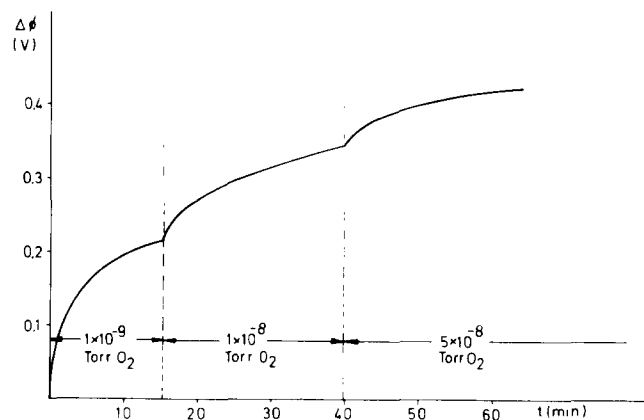


FIG. 5. Work function change of a Pt (111) surface as function of O<sub>2</sub> exposure.

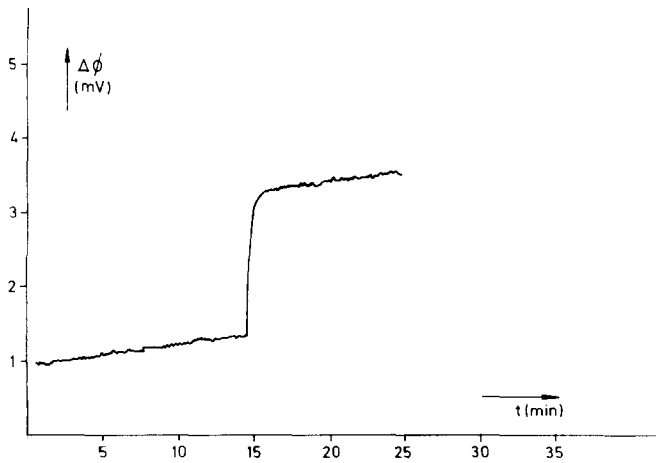


FIG. 6. Sensitivity test of the Kelvin probe.

connections. The sample was in electrical contact with a thermocouple and a liquid  $N_2$  tubing which acted as an antenna for stray fields and microphonic effects.

Figure 5 shows as a test sample the work function change of a clean PT (111) surface as function of  $O_2$

exposure. During the experiment the  $O_2$  partial pressure was increased stepwise. Detailed results will be discussed in a forthcoming publication. The sensitivity test is shown in Fig. 6. A work function change of 1.7 mV was simulated by changing  $U_2$ . A resolution of 0.1 mV at a time constant below 10 sec could easily be achieved. The observed small drifts in the wf of about 1 mV/h is probably caused by adsorption of residual gases. Notice that already a coverage change of  $10^{-3}$  monolayer of  $O_2$  might cause a wf change of 1 mV.

We would like to thank P. Kleinschmidt (Siemens AG, München) for his helpful advice and for the supply of the piezoelectric ceramic material.

<sup>1</sup> Lord Kelvin, *Phil. Mag.* **46**, 82 (1898).

<sup>2</sup> W. A. Zisman, *Rev. Sci. Instrum.* **3**, 367 (1932).

<sup>3</sup> P. P. Craig, V. Radeka, *Rev. Sci. Instrum.* **41**, 2 (1970).

<sup>4</sup> J. S. W. de Baer *et al.*, *Rev. Sci. Instrum.* **44**, 8 (1973).

<sup>5</sup> J. Hölzl, P. Schrammen, *Appl. Phys.* **3**, 353 (1974).

<sup>6</sup> R. Butz, dissertation (unpublished).

<sup>7</sup> H. J. Fett, dissertation (unpublished).

<sup>8</sup> N. A. Surplice, R. J. D'Arcy, *J. Phys. E* **3**, 477 (1970).

<sup>9</sup> K. G. Tschersich, *Vak. Tech.* **22**, (3), 93 (1975).

<sup>10</sup> M. J. Dix *et al.*, *J. Phys. E* **6**, 1099 (1973).