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# Influence of surfactant on single ion track etching

**Man[1], Leo C.T.; Apel[2], Pavel; Cheung[1], T.; Westerberg[3], Lars; Yu[1], K.N.; Zet[4], Cristian; Spohr[5], Reimar**

[1]City University Hong Kong, Department of Physics & Materials Science, Hong Kong, China;
[2]Joint Institute of Nuclear Research, Centre of Applied Physics, Dubna, Russian Federation;
[3]Uppsala University, Svedberg Laboratory, Uppsala, Sweden;
[4]Technical University Iasi, Department of Metrology, Iasi, Romania;
[5]GSI Darmstadt and EuNITT, Darmstadt, Germany

Corresponding Author: r.spohr@gsi.de

**Abstract**. The influence of the alkali resistant surfactant Dowfax 2A1[1] on ion track etching in 30 μm polycarbonate foils at low etch rate (5 M NaOH at 41.5±2°C) is studied using electro conductivity measurements. Above $10^{-4}$ vol.-% surfactant concentration short, reproducible break-through times are achieved. Above 0.1 vol.-% surfactant concentration cylindrical channels with radius > 0.9 μm can be formed.

## 1. Introduction

Ion track etching [1] requires at least one energetic heavy ion or fission fragment to supply the energy necessary for rendering a cylindrical volume around the ion path developable in a dielectric solid. It opens a new route to micro technology decisively different from conventional lithography [2]: While conventional lithography is based on a mask, the ion track technique works usually without a mask. In contrast to lithography, the ion track technique can be applied to a wide selection of dielectrics [3].

The ion track technique enables narrow, high aspect ratio structures with defined cutting angle whereby each structure is exactly due to one penetrating ion. Various shapes are possible, such as narrow and wide cones, spherical troughs, barrels, and bottle necked structures [4]. Replica techniques are used to create spatially modulated textured objects such as wires with axially [5] (Pira94) or radially [6] varying composition.

Track etching and electro-replication can be studied in real-time using electro conductivity measurements while SEM can be used for verification. Surfactants improve the wetting of hydrophobic polymers. They aggregate as monolayers on the polymer surface [7], reduce etch attack [8] and favor the formation of cylindrical channels. The report describes the effect of the (acid and alkali resistant) surfactant Dowfax 2A1 on ion track etching at low etch rates. Above about 1 μm channel diameter, the result is essentially a cylindrical channel.

[1] Alkyldiphenyloxide Disulfonate, surfactant Dowfax 2A1: Dow Chemicals: http://www.dowchemicals.com/

 

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## 2. Experimental technique

### 2.1. Electrolytic cell

A 30 µm thick polycarbonate membrane with a single heavy ion track (11.3 MeV/u U-238, [9]) is inserted into an electrolytic cell consisting of two cell halves with flat sealing surfaces facing the central membrane ([10]; [11]). The membrane is etched on both sides with 5 M NaOH at (41.5±2) °C while applying over the membrane an alternating voltage of 1 kHz frequency at 0.1 V amplitude using gold electrodes. From the resulting current the channel diameter is determined.

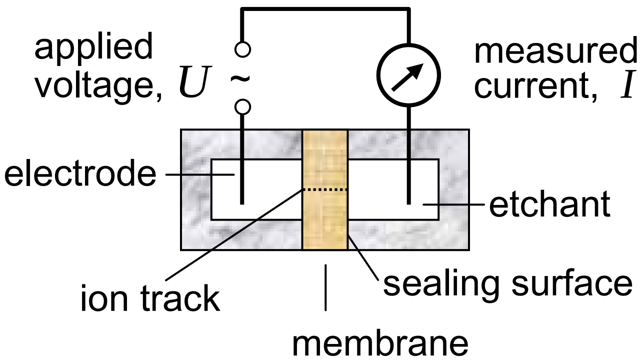


Fig. 1 Principle of electrolytic cell for real-time control of track etching and electro replication

## 3. Results

### 3.1. Break-through time

The surfactant enables a firm contact between the etching medium and the hydrophobic membrane by adsorbing on the membrane. A small concentration (≥$10^{-3}$ vol.-%) is sufficient to ensure nearly constant reproducible break-through time.

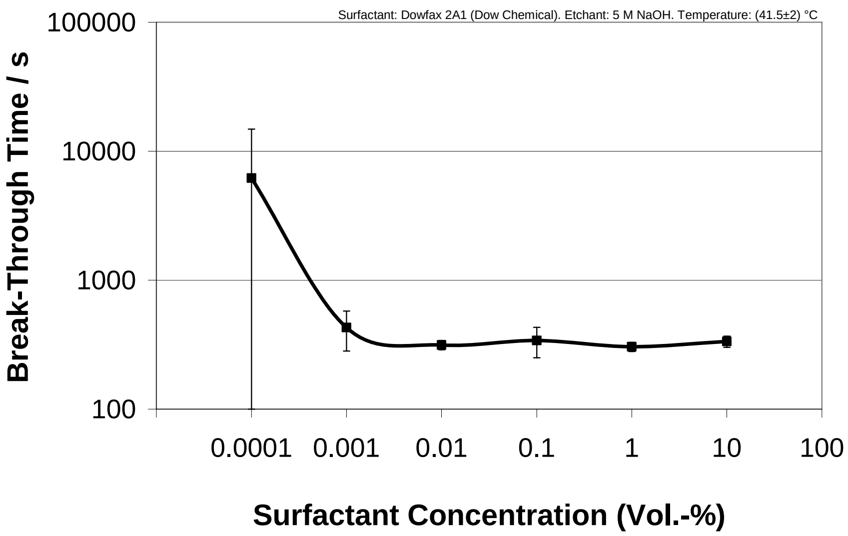


Fig. 2 Influence of surfactant concentration on break-through time. A reproducible break-through time is obtained for a surfactant concentration ≥0.001 vol.-%.

### 3.2. Radial etch rate

During etching the channel radius increases with time. The surfactant decreases but stabilizes the etch rate. With increasing surfactant concentration the radius becomes increasingly a linear function of time.

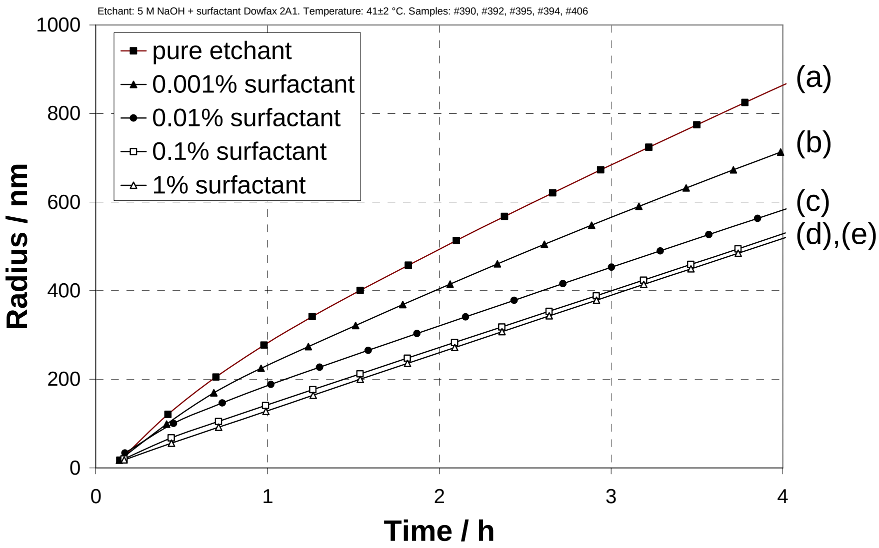


Fig. 3 Radius as function of time. With increasing surfactant concentration, (a) to (e), the radius becomes gradually an almost linear function of time.

### 3.3. Electro replication

To verify the electro conductivity measurement, electro replication of the resulting channel is used, leading to hard, compact, polycrystalline copper wires that can be observed by scanning electron microscopy. For track diameters above 2 µm, the correspondence of electro conductivity measurements and SEM observations is better than 5%.

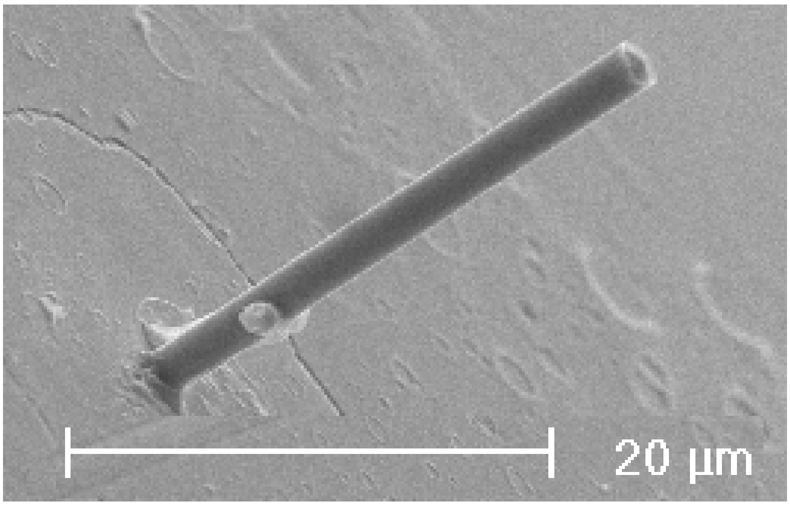


Fig. 4 Compact wire. Copper replica of cylindrical ion track channel electro deposited at 10 nA maximum current. Wire diameter 2.2 µm, wire length 25.6 µm.

## 4. Discussion

The interplay between etch attack and protection by a surfactant, combined with different molecular mobilities, enables to control track shapes [8], [4]. At low concentration of the etchant and low temperature the etch rate is low. In this case, the protecting action of the surfactant dominates. The molecules of the surfactant penetrate into the track opening and aggregate into a protective sheath along the pore wall before the etchant starts reacting. Lateral etching is suppressed and longitudinal etching prevails. The self-organized aggregation of surfactant molecules on the inner wall of etched ion tracks leads to cylindrical tracks.

## 5. Acknowledgements

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