MICROFLUIDIC POLYIMIDE CHIPS FABRICATED BY LAMINATION PROCESSES FOR X-RAY SCATTERING APPLICATIONS

Gerardo Perozziello[1,2], Rossella Catalano[1], Giuseppina Simone[3], Patrizio Candeloro[1], Natalia Malara[1], Stefania Santoriello[4], Rosanna La Rocca[4], Francesco De Angelis[4], Angelo Accardo[4], Manfred Burghammer[5], Emanuela Di Cola[5], Giovanni Cuda[1,2], Christian Riekel[5], Enzo Di Fabrizio[4,1]

[1]Lab. BioNEM (Bio Nano Engineering and Technology for Medicine), University of Catanzaro, Italy;
[2]Biotecnomed Scarl, Italy
[3]CRIB, Univerity of Naples (Federico II), Italy;
[4] Nanostructure department, Italian Institute of Technology, Italy;
[5]European Synchrotron Radiation Facility (Grenoble),

ABSTRACT

A polyimide microfluidic chip was developed for X-ray scattering applications based on a reliable and inexpensive lamination process. The device has been characterized in terms of bonding resistance and X-ray scattering and transmission. The microfluidic chip will be used to study protein conformational changes under controlled shear stress conditions which could play a role in human microcirculation.

KEYWORDS

Polyimide chips, lamination, X-ray analysis.

INTRODUCTION

The study of early stages of reaction kinetics is challenging for many applications such as protein binding, folding, and structural changes of biomolecules [1, 2]. Microfluidics combined with X-ray scattering techniques allows probing minute amount of samples at a small time scale and is a promising candidate for such applications. Our aim was to develop a highly X-ray transparent microfluidic chip for detecting small variations of X-ray scattering during reaction kinetics. The fabrication process should be simple and the chip geometry easily changeable.

EXPERIMENT

A picture of the device is shown in Figure 1A. A 13μm thick polyimide (PI) film with a high X-ray transmission [3] was punched to create inlets and outlets. It was then laminated on a 50μm thick photosensible dry resist layer (PR) at a temperature of 120°C. The laminated PR was aligned by photolithography under a mask, exposed for 30 s under UV light and developed to reproduce the microfluidic layout. Finally, a PI-cover was laminated on top of the other layers to seal the device. The device was interconnected to a syringe pump by a frame. It was shown to be leak tight up to a pressure of 0.97bar.

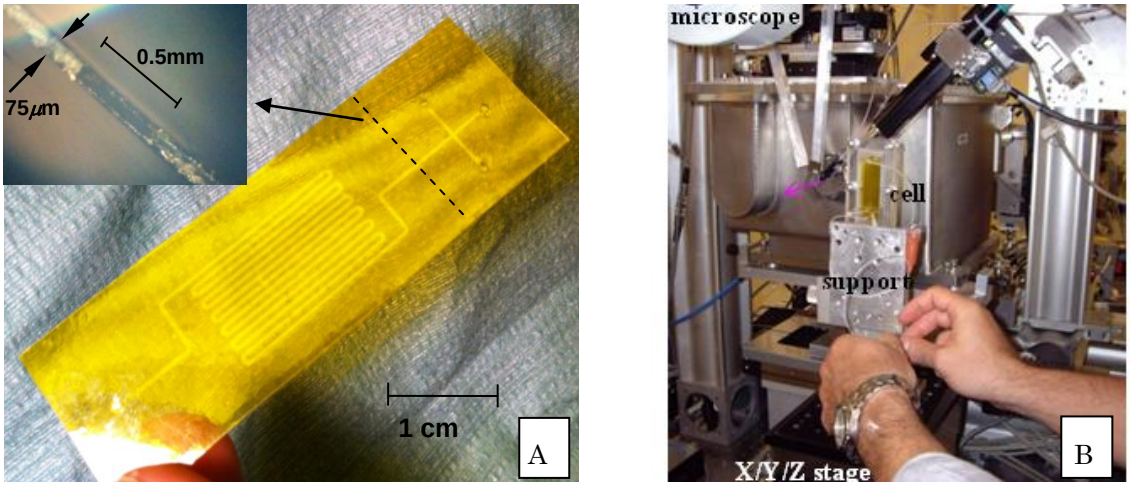

Figure 1: A: Top-view of the microfluidic device which has an overall length of about 70 mm and zoom-in of the channel cross section. B: Installation of the microfluidic cell frame on the ID13 beamline of the European Synchrotron Radiation Facility.

The microfluidic device was characterized by X-ray microbeam scattering at the ID13 beamline of the European Synchrotron Radiation Facility using an about 1 μm diameter monochromatic beam at a wavelength of about 1 Å (Figure 1B).

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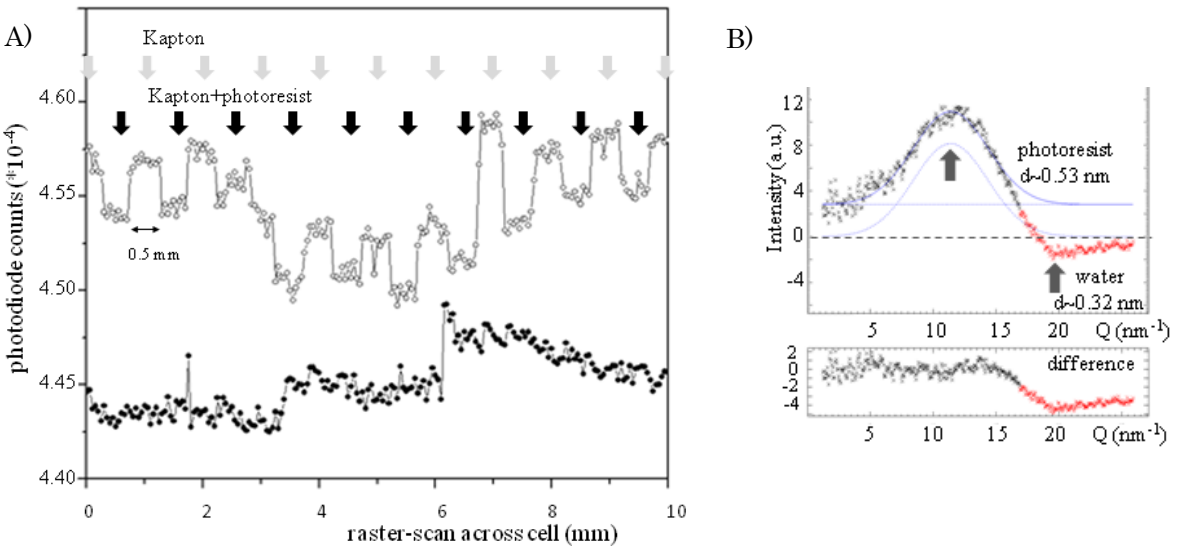

Figure 3: A: Variation of X-ray transmission across the empty (open circles) and water-filled (full circles) device. The PI+PR transmission of the empty cell is lower than the PI transmission. The center of the empty channels is indicated by grey arrows and the center of the PR-filled stripes by dark arrows. (Kapton is a brand name for PI). B: Above: difference diffraction pattern of PI+PR minus PI+water. The PR-peak has been fitted by a Gaussian profile. The red part has not been included in the fit: Below: pattern obtained after subtraction of the fitted peak. ($Q=4\pi\sin\Theta/\lambda$, Θ is the Bragg angle, λ the wavelength)

The X-ray transmission of the empty and water-filled chip was probed by raster-scans using a photodiode detector (Figure 3A). The periodic variation in X-ray transmission of the empty chip reflects the succession of less absorbing PI and more absorbing PI+PR layers in agreement with the device structure. The additional water absorption of the water-filled chip results in practically the same density as for the PI+PR layers and suppresses the periodic X-ray transmission variation. A residual nonperiodic X-ray transmission modulation across the water-filled cell reveals small local variations of the thickness of the absorbing components.
We obtained X-ray diffraction pattern from the water-filled cell in transmission geometry by using a CCD with X-ray converter screen.

RESULTS

The azimuthally integrated difference diffraction pattern of PR+PI minus PI+water scattering shows a residual peak due to PR-scattering and a negative peak due to water. The PR-peak can be fitted by a Gaussian profile. (Figure 3B, top). The difference pattern obtained after subtraction of the fitted peak shows a clean baseline at the PR-peak position (Figure 3B, below).
The fitted PR-peak can be accurately subtracted from the PI+PR scattering to obtain the pure PI scattering. The scattering patterns of PI+water and PI+PR is shown in Figures 5A,B. The patterns are dominated by narrow PI Bragg peaks and broad diffuse peaks due to PI, PR and water scattering. The corresponding azimuthally integrated patterns are shown in Figures 5B,C. The fitted PR-scattering from Figure 4 is included in Figure 5D. The pure PI scattering shows a mixture of narrow Bragg peaks and broad diffuse scattering characteristic for a semicrystalline polymer (Figure 5E). Finally, the subtraction of polyimide scattering from the PI+water scattering (Figure 5C) reveals the diffuse water scattering in the chip (Figure 5F).

CONCLUSIONS

The microfluidic device shows a high X-ray transmission and the residual X-ray scattering from the PI windows can be subtracted with a high precision. Reaction processes involving small scattering signals could thus be well studied. The X-ray transmission can be further increased by thinning the polyimide film. The simple fabrication process allows an easy modification of the device geometry.

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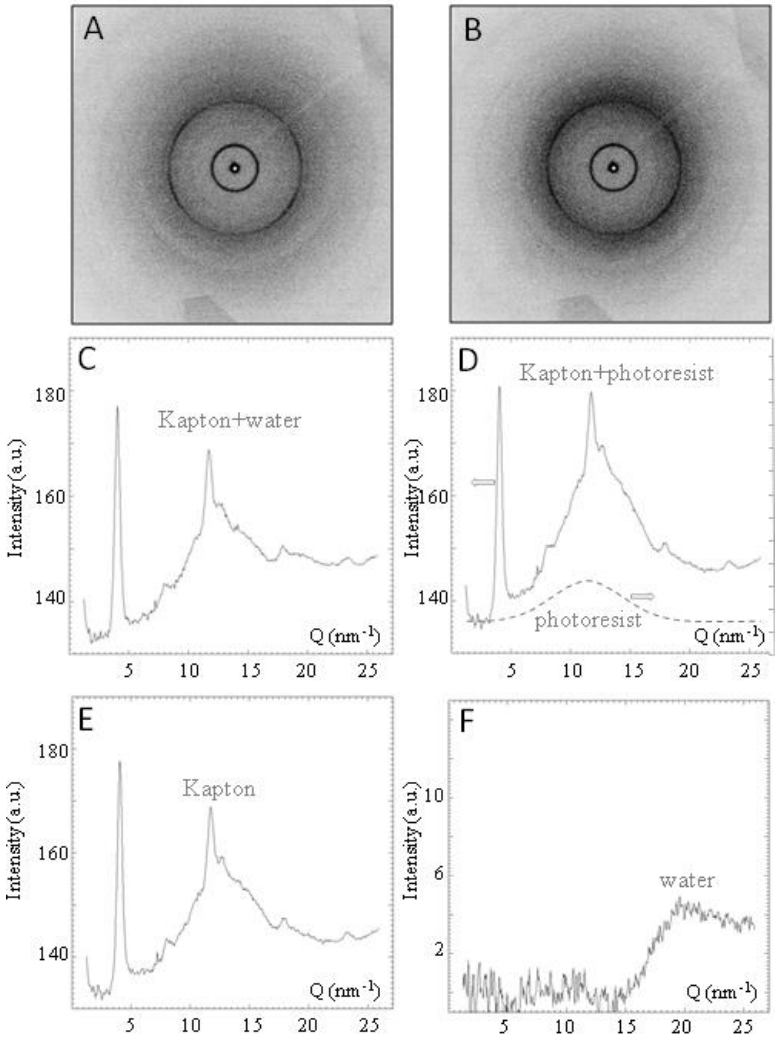

Figure 5: A, B: PI+water and PI+PR scattering; C,D: azimuthally integrated PI+water and PI+PR scattering. The barred curve is the fitted PR-scattering from Fig. 4,above. E: PI scattering obtained by subtracting the PR-scattering from the PI+PR scattering in D. F: water scattering obtained by subtracting (E) from (C). (Kapton is a brand name for PI)

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CONTACT

Gerardo Perozziello +39 3887413460 or gerardo.perozziello@unicz.it