Analysis of the robustness of Hierarchical hydrophilic and hydrophobic nanostructures

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OUTLINE

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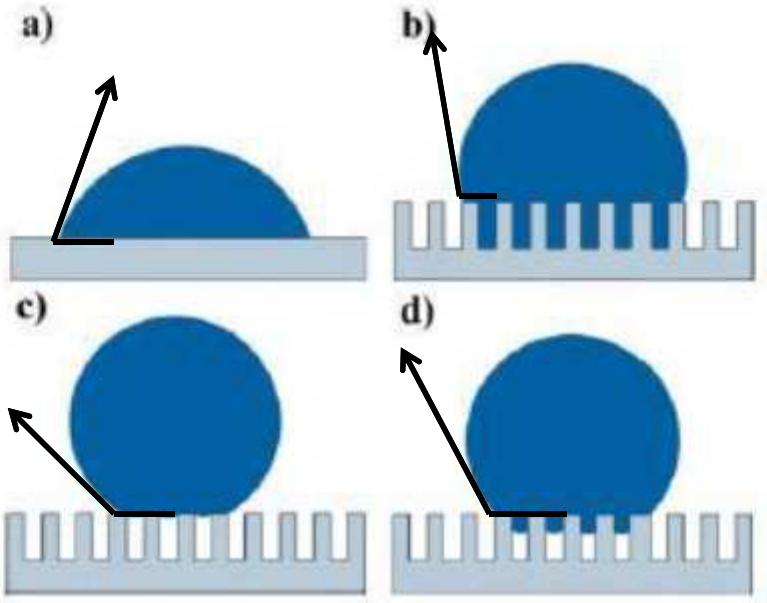
OBJECTIVE

Study the wettability variation on roughness induced polymer materials, considering robustness issues.

THEORY

Wettability is the affinity of a surface to the fluid of interest and is typically described by the contact angle at the triple contact line between vapor, liquid and the solid surface. Contact angle on a smooth surface is only a function of the fluid and surface materials. If the surface is not smooth, the contact angle changes.

THEORY

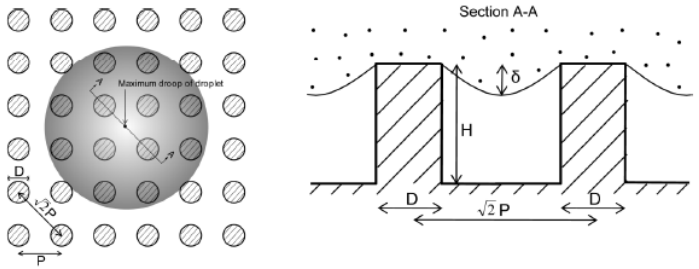


Different liquid states depending on surface rughness and liquid tension:
a) Drop on a flat substrate b) Wenzel mode c) Cassie-Baxter mode d) Intermediate mode.

Transition from Cassie-Baxter to Wenzel regime depends upon the roughness and radius of droplet.

THEORY

The curvature of a droplet is governed by Laplace eq. which relates pressure inside the droplet to its curvature. The maximum droop of the droplet on an ordered pillars pattern



$$\delta \approx \frac{(\sqrt{2}P - D)^2}{R}$$

If $\delta \geq H$ Transition from Cassie-Baxter regime to Wenzel regime

IN DETAIL STUDY

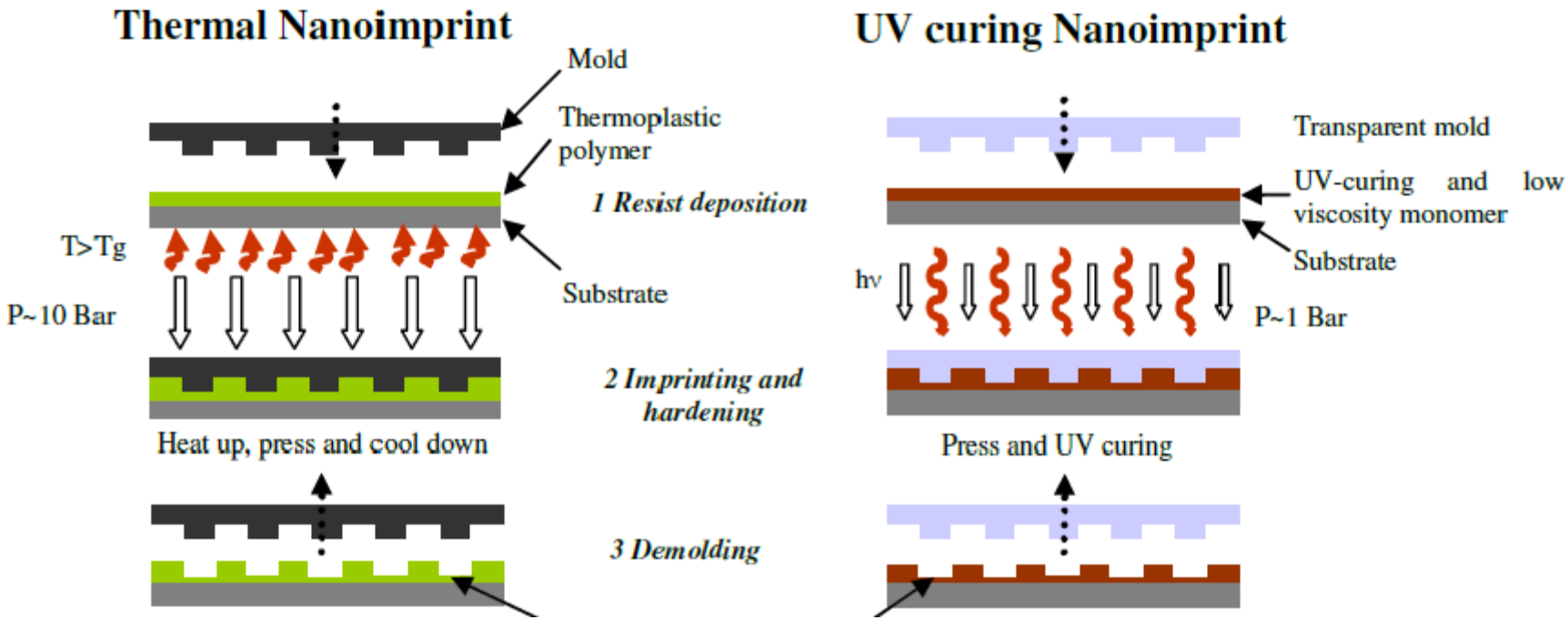
The influence on wetting behaviour of patterned surface with ordered pillar structures varying height, diameter and pitch. We will focus on pattern parameters, drop size will not be considered.

Feature geometry influence on ordered patterns, from pillars (flat top end) to cones (with sharp top end), to study the influence on wetting of such parameters.

Different hierarchical structures (ordered or not).

Finally, robustness of the different roughness patterns is discussed.

SAMPLE PREPARATION



Si Master stamp was replicated on OMS (UVNIL). Afterwards the mould was used for texture replication on polymeric material (Thermal NIL).

SAMPLE PREPARATION

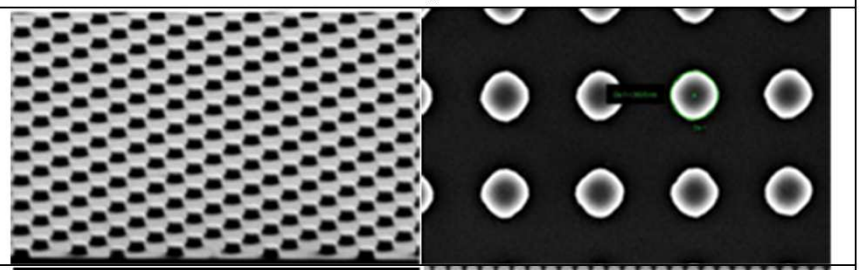
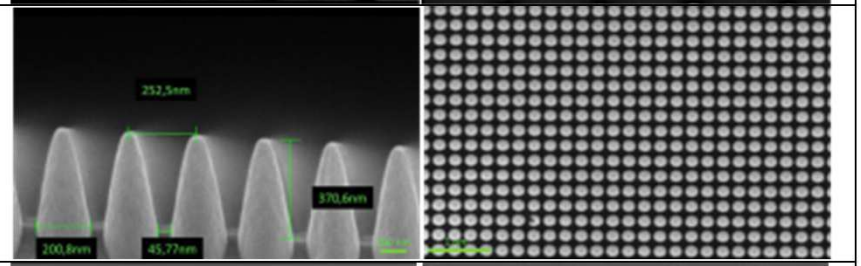
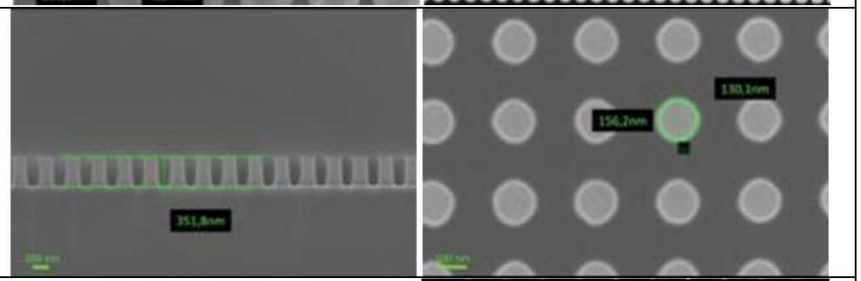
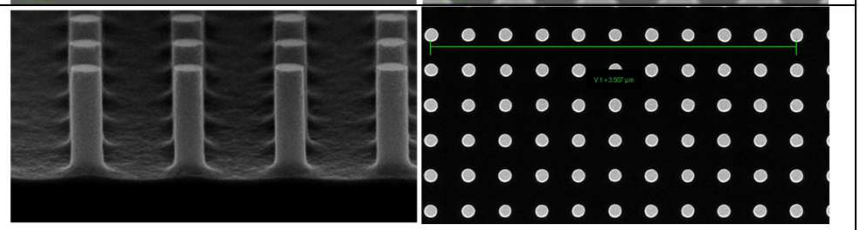
THERMAL NIL

Thermal NIL process was carried out for surface modification on several thermoplastic materials.

Material	Tg	T process	p process	CA bibliography
PC Polycarbonate)	150	195	7bar	82
PMMA (Polymethylmethacrylate)	95	205	7bar	70,9
COC (Cyclic Olefin Copolymer)	138	150	7bar	88
CAB (Cellulose Acetate Butyrate)	100	190	7bar	
CA (Celluylose Acetate)	60	185	7bar	58-72
CAP (Cellulose Acetate Propionate)	30	195	7bar	74-67,5

SAMPLE PREPARATION

PATTERNS

Geometry	Images
Pillars 700nm	
Cones 250nm	
Pillars 300nm	
Pillars 350nm	

Geometry	Aspect Ratio	Pitch	height	Diameter
Pillars 700nm	0,44	700nm	150nm	340nm
Cones	1,85	250nm	370nm	Distance among cones (base) <50nm
Pillars 300nm	3	300nm	360nm	120nm
Pillars 350nm	3	350nm	360nm	120nm

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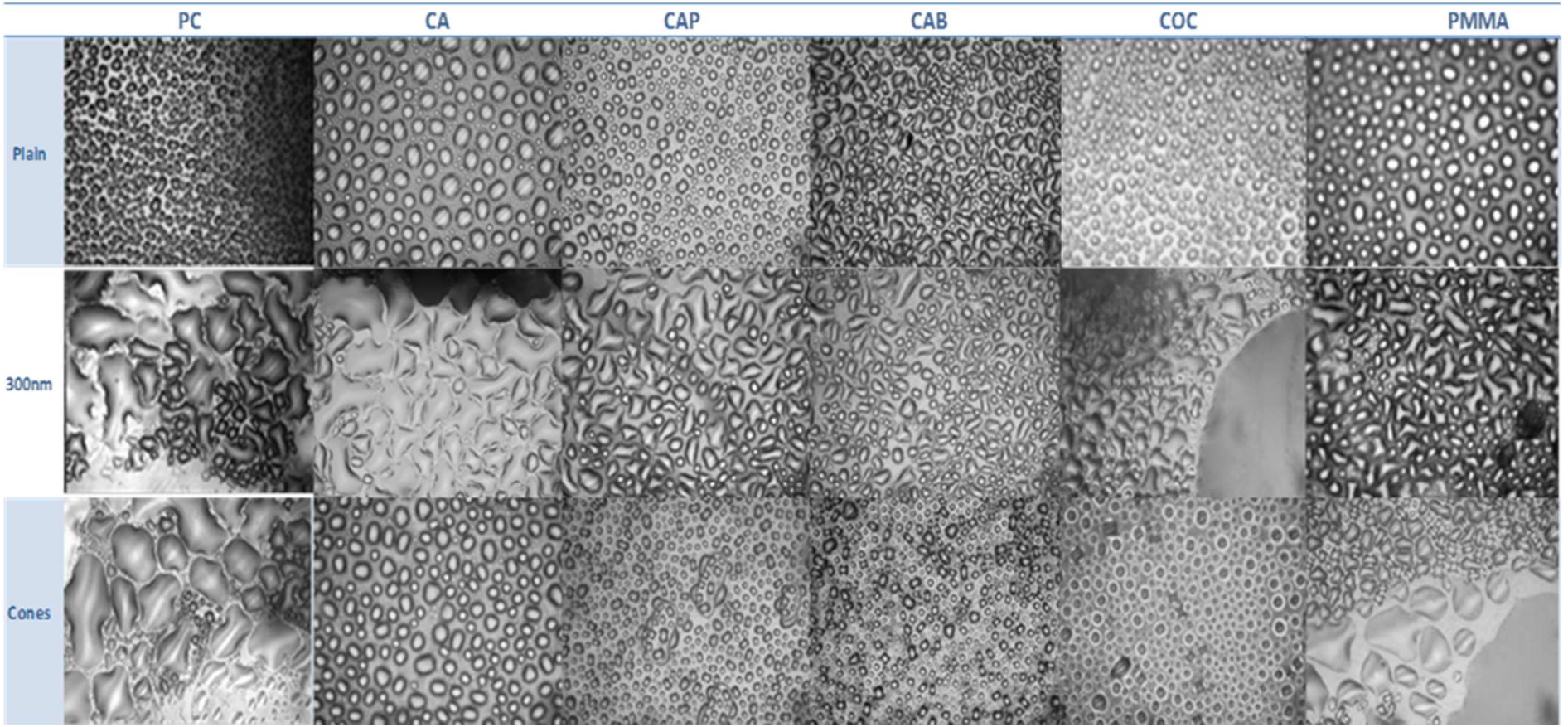
RESULTS

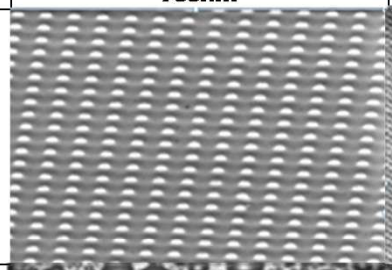
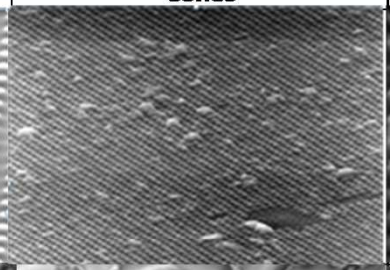
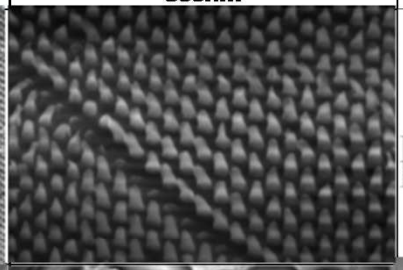
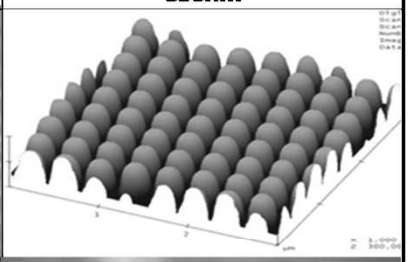
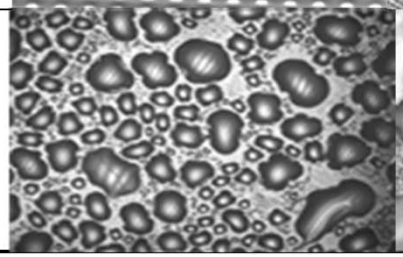
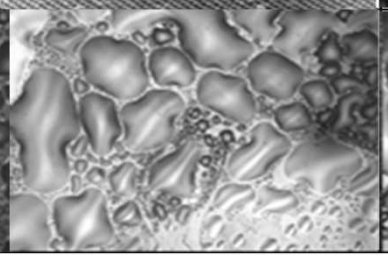
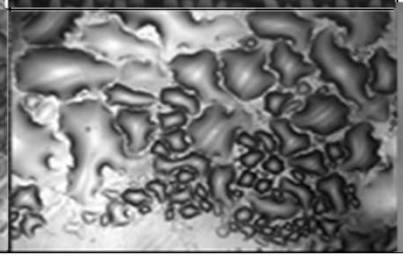
NANOIMPRINTED POLYMER MATERIALS

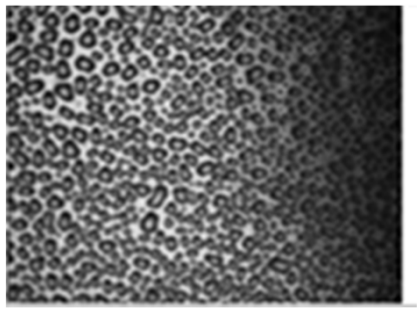


PC and CA will be further developed for other textures because major surface roughness response from the wettability point of view at the 300nm pitch pillars stamp.

RESULTS

NANOIMPRINTED PC

Geometry	700nm	Cones	300nm	350nm
Image Texture				
Water deposition				



PC replicated geometry	Pitch	height	Diameter
Pillars 700nm	700nm	146nm	340nm
Cones	250nm	128nm	Distance among cones (base) <50nm
Pillars 300nm	300nm	315nm	120nm
Pillars 350nm	350nm	357nm	120nm

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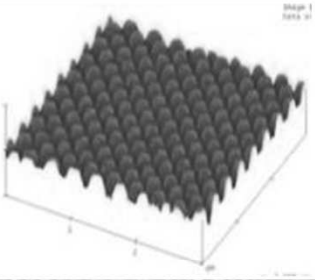
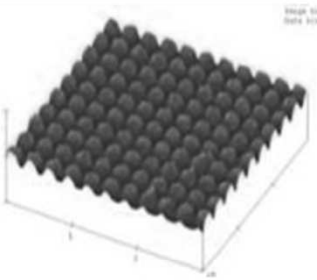
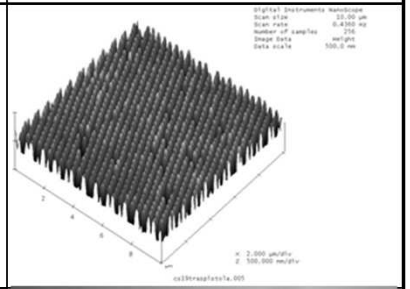
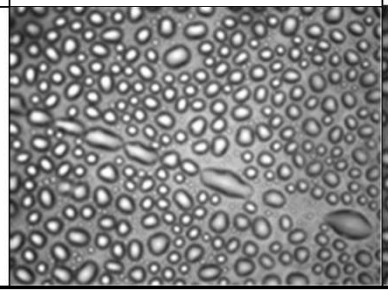
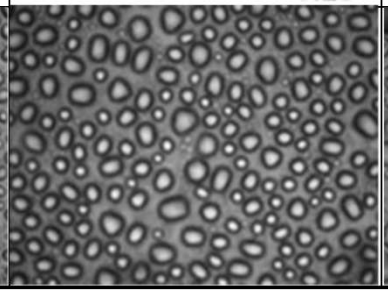
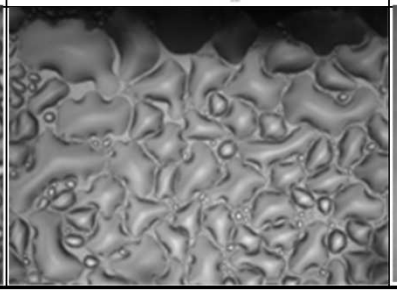
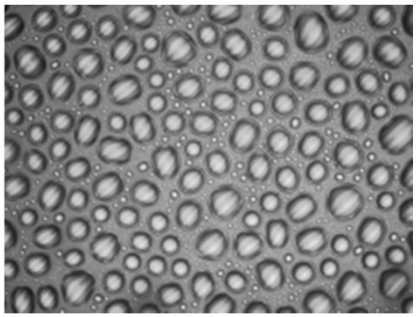
RESULTS

NANOIMPRINTED CA

Geometry	700nm	Cones	300nm	350nm
Image Texture				
Water deposition				



PC replicated geometry	Pitch	height	Diameter
Pillars 700nm	700nm		340nm
Cones	250nm	95nm	Distance among cones (base) <50nm
Pillars 300nm	300nm	311nm	120nm
Pillars 350nm	350nm	345nm	120nm

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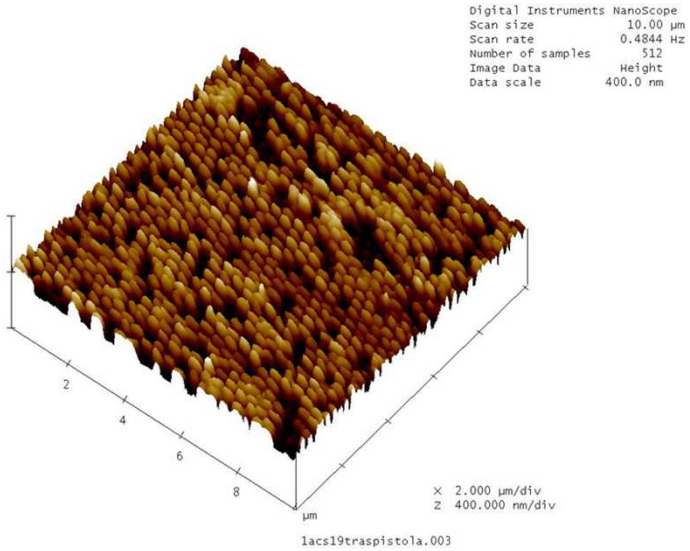
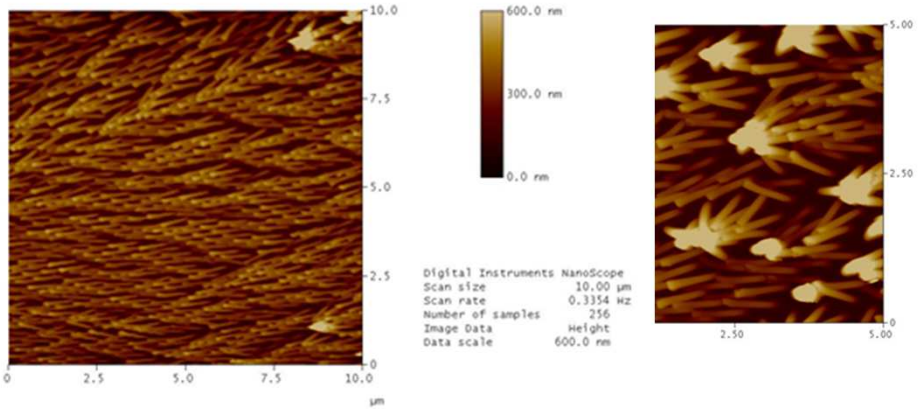
RESULTS

ROBUSTNESS of PC and CA PILLARS



AC samples after soft mechanical test.

Not as hydrophilic.



PC samples after soft mechanical test.

Not as hydrophilic.

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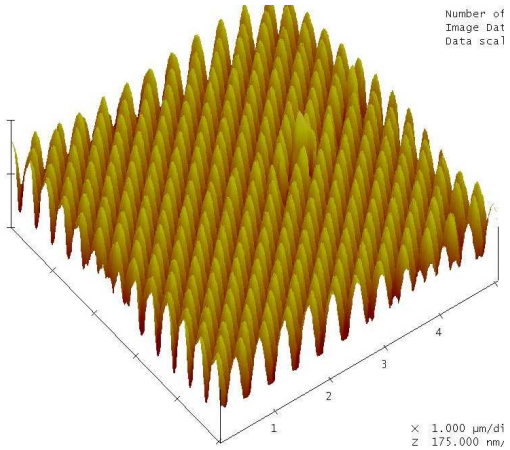
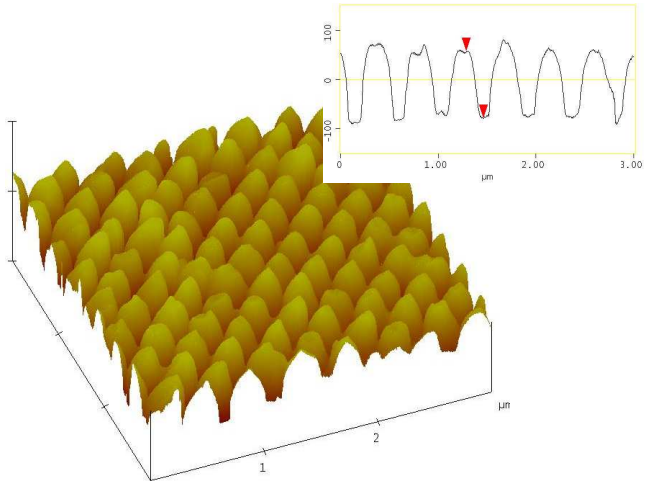
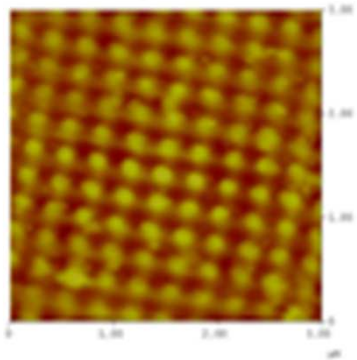
RESULTS ROBUSTNESS of HIERARCHICAL structures

300nm texture replicated on CAB etched by NaOH





Etched pillars height 135nm



Hydrophilic texture replicated on CAB. After soft mechanical test still hydrophilic.

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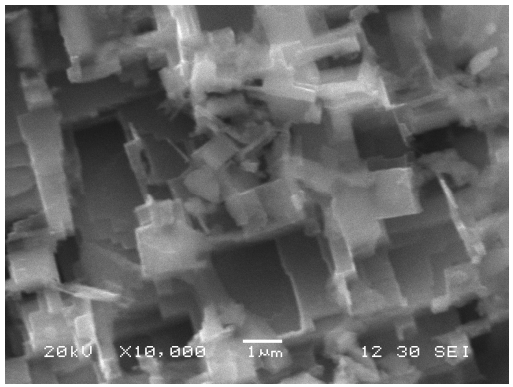
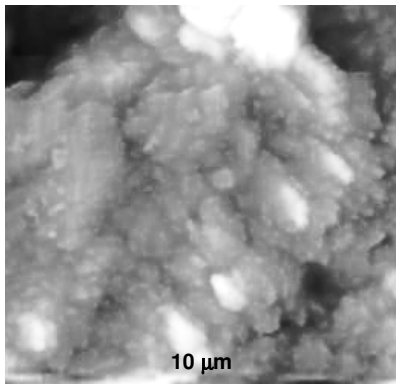
RESULTS

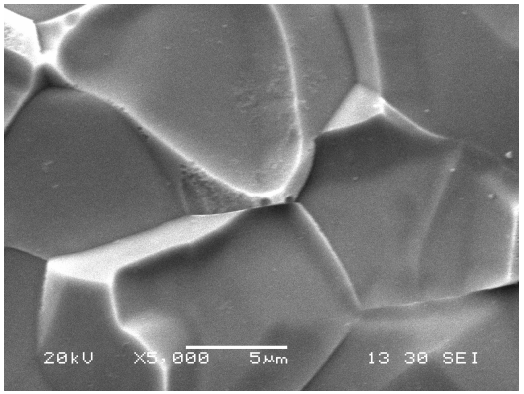
ROBUSTNESS of HIERARCHICAL structures

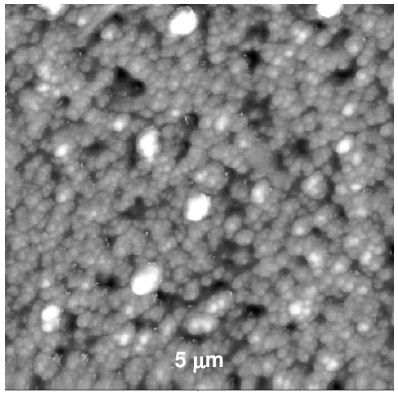




SEM image of etched aluminium and AFM image of surface for micrometre (2,5µm Ra) and nanometre roughness observation (136nm Ra).

Hydrophobic structure. After soft mechanical test still hydrophobic.





SEM image of etched steel and AFM image of surface for micrometre (0,51µm Ra) and nanometre roughness observation (16 nm Ra).

Hydrophilic structure. Not tested yet.

CONCLUSIONS and FUTURE WORK

On tested polymers HAR ordered patterns with controlled pitch are highly hydrophilic solutions, though very low robustness is observed on them.

Studied hierarchical micro/nanostructures seem to show enhanced wetting performance (hydrophilic or hydrophobic) together with high robustness, though further study is required.

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Thank you

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