Soft Lithography

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Angew. Chem. Int. Ed. **1998**, *37*, 550-575.

Table 2. Non-photolithographic methods for micro- and nanofabrication.

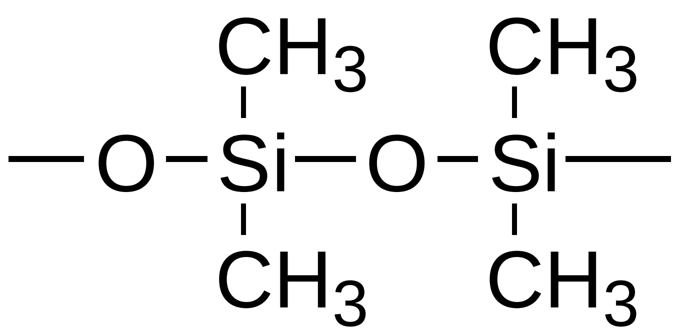
Method	Resolution[a]	Ref.
injection molding	10 nm	[15, 16]
embossing (imprinting)	25 nm	[17, 18]
cast molding	50 nm	[19, 20]
laser ablation	70 nm	[21, 22]
micromachining with a sharp stylus	100 nm	[23]
laser-induced deposition	1 μm	[24]
electrochemical micromachining	1 μm	[25]
silver halide photography	5 μm	[26]
pad printing	20 μm	[27]
screen printing	20 μm	[28]
ink-jet printing	50 μm	[29, 30]
electrophotography (xerography)	50 μm	[31]
stereolithography	100 μm	[32]
soft lithography		[33]
microcontact printing (μCP)	35 nm	[34, 84f]
replica molding (REM)	30 nm	[35]
microtransfer molding (μTM)	1 μm	[36]
micromolding in capillaries (MIMIC)	1 μm	[37]
solvent-assisted micromolding (SAMIM)	60 nm	[38]

[a] The lateral dimension of the smallest feature that has been generated. These numbers do not represent ultimate limits.

Soft Lithography

A group of non-lithographic techniques for micro- and nano-fabrication using a soft elastomeric stamp.

poly(dimethylsiloxane)



Stamp Replication Process

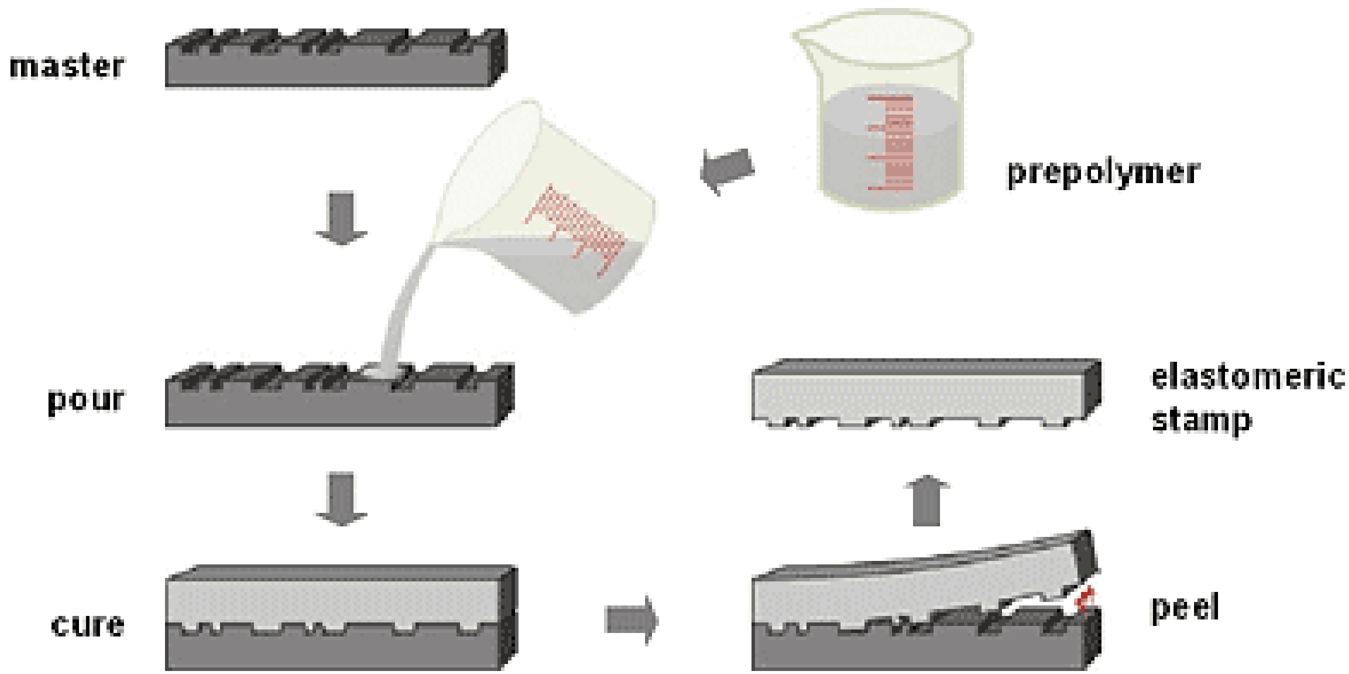
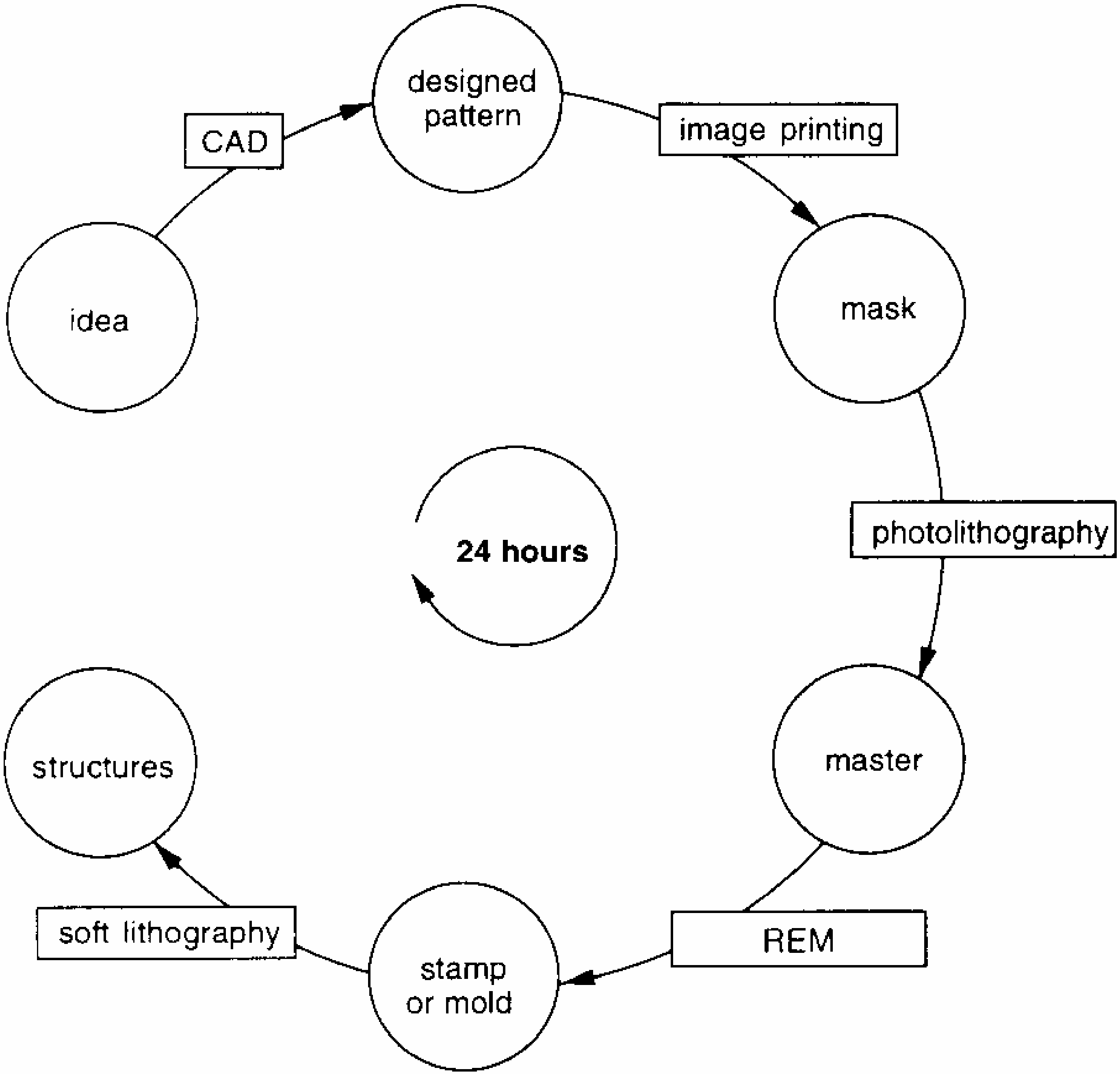


Fig.2 The stamp replication process: A master with a negative of the desired pattern is cast with a pre-polymer. After curing the polymer, the elastomeric stamp is peeled off the master and ready for microcontact printing.


designed pattern
image printing
mask
photolithography
master
REM
stamp or mold
soft lithography
structures
idea
CAD
24 hours

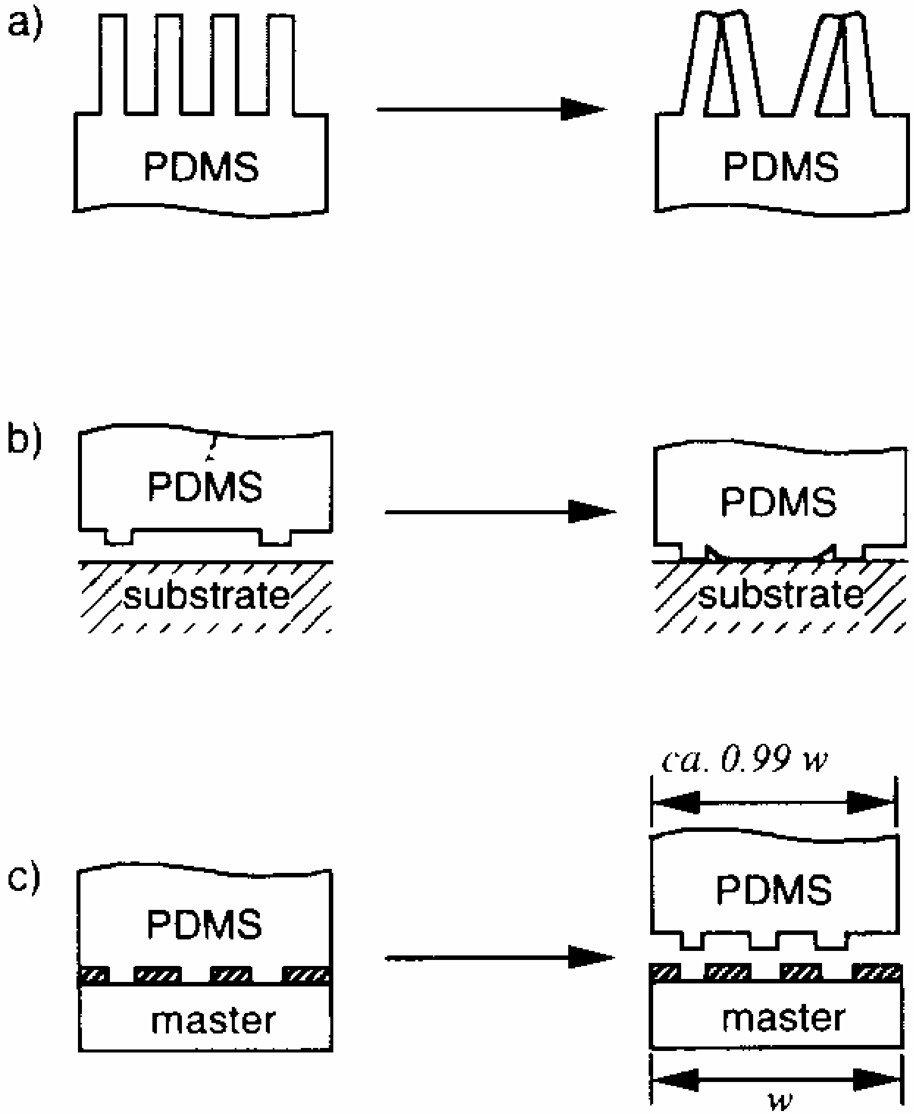


Figure 7. Schematic illustration of possible deformations and distortions of microstructures in the surfaces of elastomers such as PDMS. a) Pairing, b) sagging, c) shrinking.

Microcontact printing (μCP)

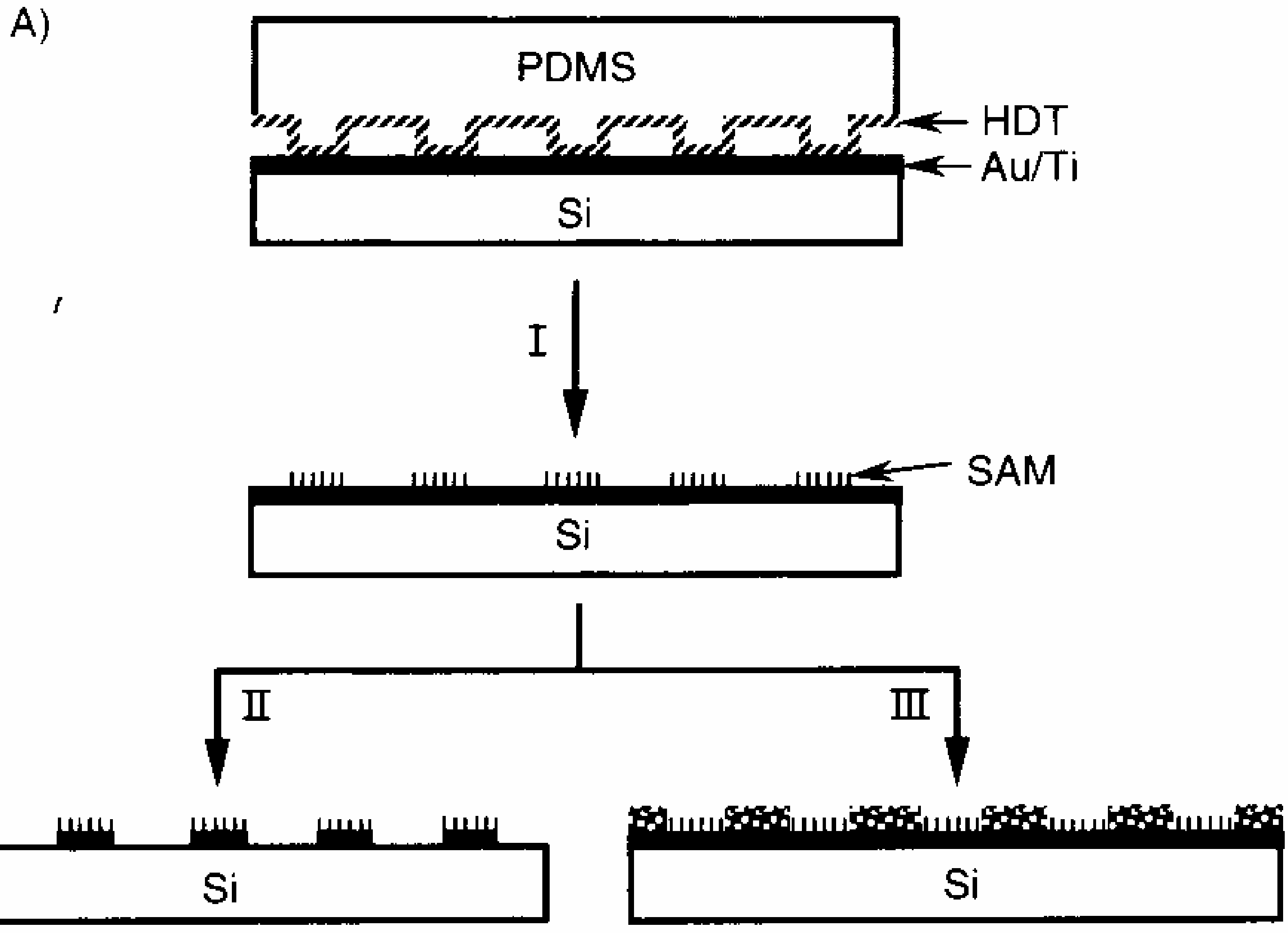
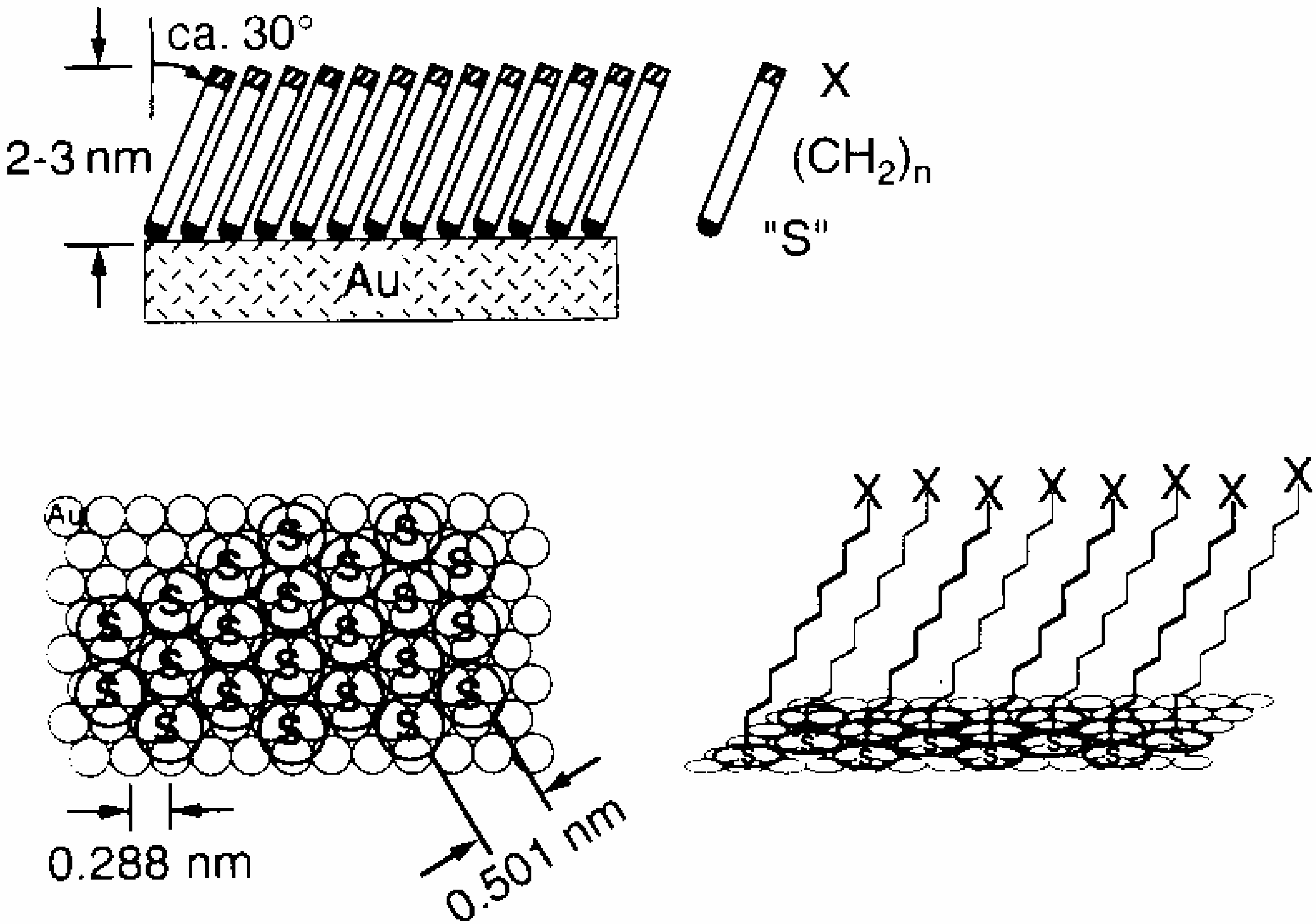


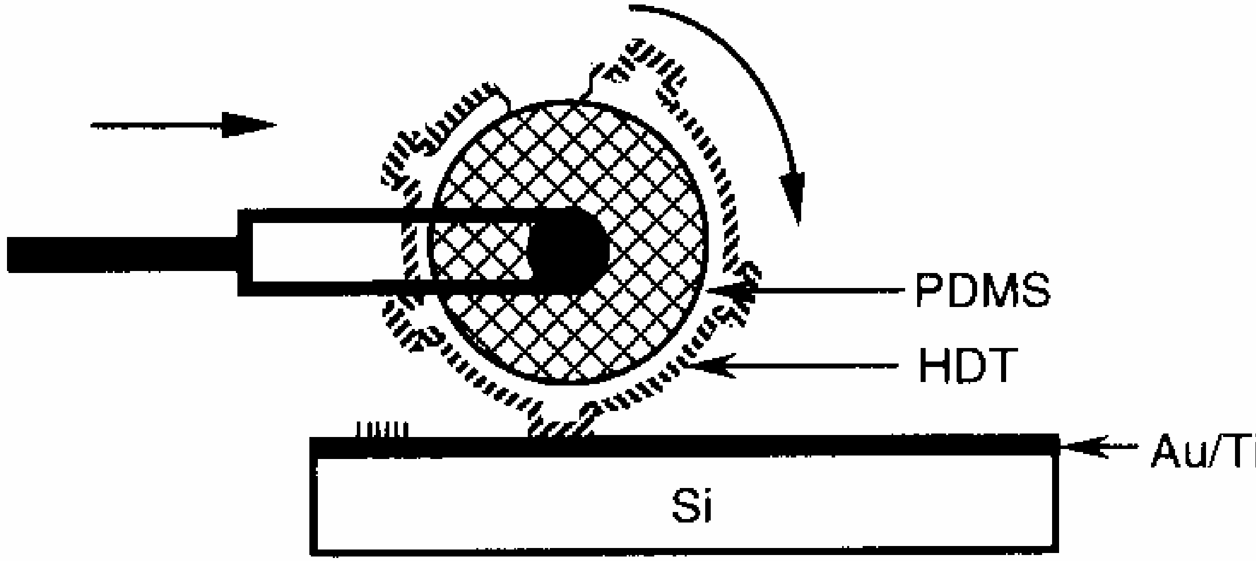
Table 4. Substrates and ligands that form SAMs.

Substrate	Ligand or Precursor	Binding	Ref.
Au	RSH, ArSH (thiols)	RS–Au	[39, 46, 47
Au	RSSR′ (disulfides)	RS–Au	[39, 46, 48
Au	RSR′ (sulfides)	RS–Au	[39, 46, 49
Au	RSO_2H	RSO_2–Au	[50]
Au	R_3P	R_3P–Au	[51]
Ag	RSH, ArSH	RS–Ag	[39, 52]
Cu	RSH, ArSH	RS–Cu	[39, 53]
Pd	RSH, ArSH	RS–Pd	[39, 54]
Pt	RNC	RNC–Pt	[39, 55]
GaAs	RSH	RS–GaAs	[56]
InP	RSH	RS–InP	[57]
SiO_2, glass	$RSiCl_3$, $RSi(OR')_3$	siloxane	[39, 46, 58
Si/Si–H	$(RCOO)_2$ (neat)	R–Si	[59]
Si/Si–H	$RCH{=}CH_2$	RCH_2CH_2Si	[60]
Si/Si–Cl	RLi, RMgX	R–Si	[61]
metal oxides	RCOOH	$RCOO^- \cdots MO_n$	[62]
metal oxides	RCONHOH	$RCONHOH \cdots MO_n$	[63]
ZrO_2	RPO_3H_2	$RPO_3^{2-} \cdots Zr^{IV}$	[64]
In_2O_3/SnO_2 (ITO)	RPO_3H_2	$RPO_3^{2-} \cdots M^{n+}$	[65]

$$X(CH_2)_nSH + Au^0 \longrightarrow X(CH_2)_nS^-Au^I + 1/2\ H_2$$



B)



C)

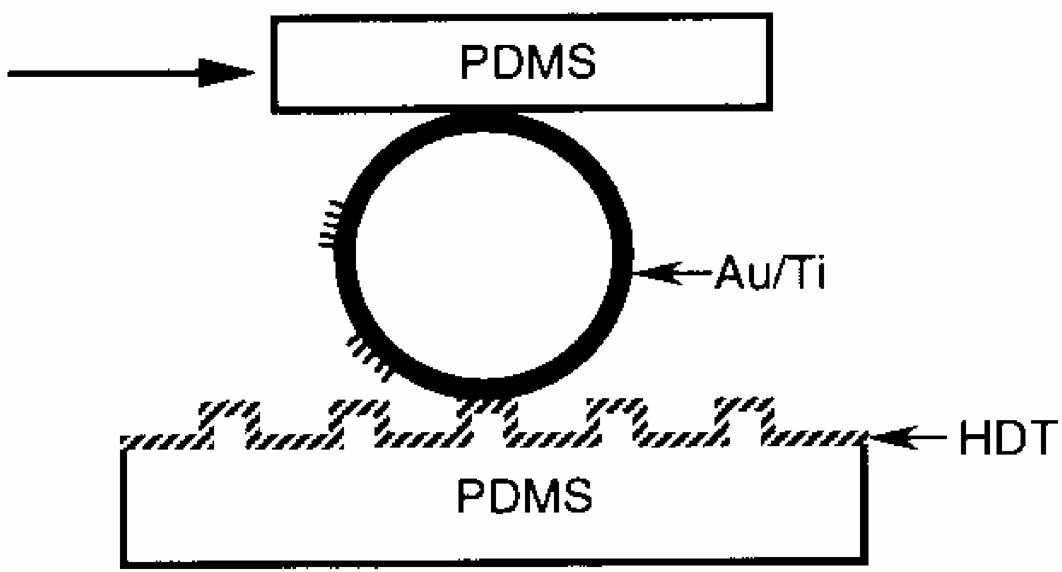
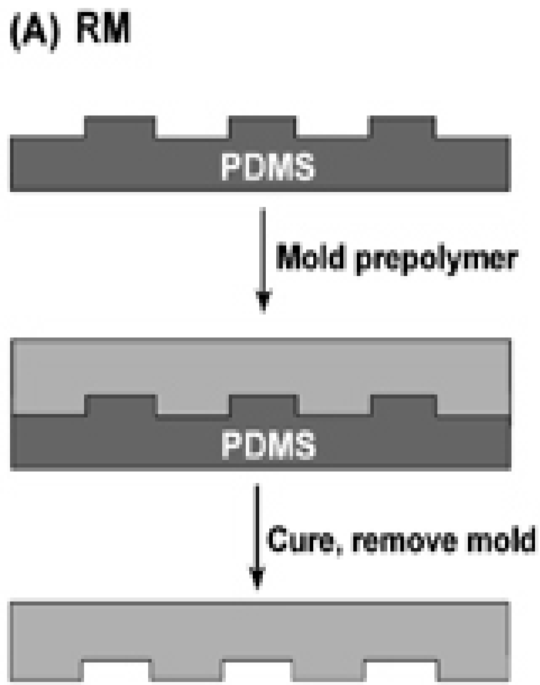


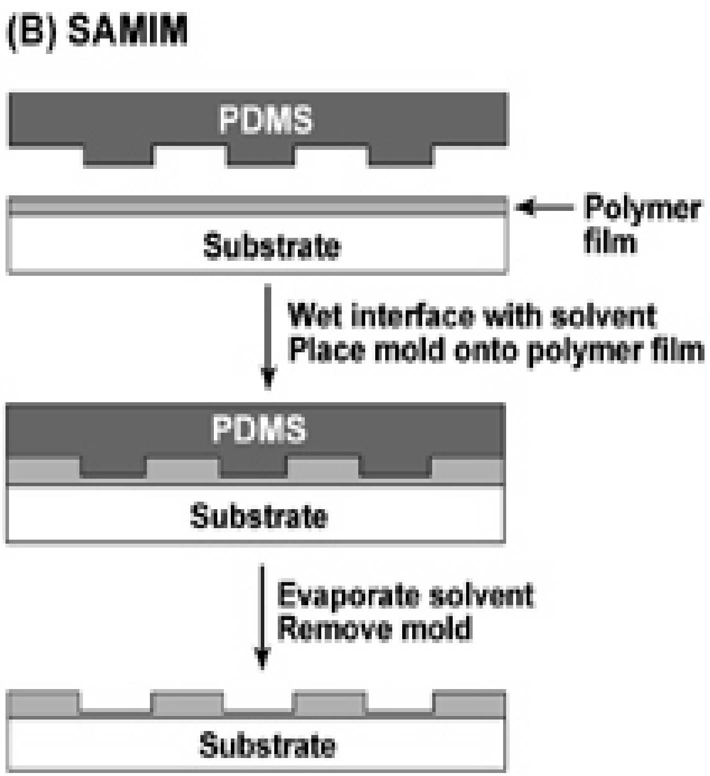
Table 5. Techniques for characterizing SAMs of alkanethiolates on gold.

Property of SAMs	Technique	Ref.
structure and order	scanning probe microscopy	[66, 67]
	STM, AFM, LFM	[135]
	infrared spectroscopy	[39e, 68]
	low-energy helium diffraction	[69]
	X-ray diffraction	[70]
	transmission electron diffraction	[71]
	surface Raman scattering	[72]
	sum frequency spectroscopy (SFS)	[73]
composition	X-ray photoelectron spectroscopy (XPS)	[74]
	temperature programmed desorption (TPD)	[75]
	mass spectrometry (MS)	[76]
wettability	contact angle	[77]
thickness	ellipsometry	[78]
coverage and/or degree of perfection	quartz crystal microbalance (QCM)	[79]
	surface acoustic wave (SAW) device	[80]
	electrochemical methods	[81]
defects	STM and AFM	[66, 67]
	wet etching	[82]

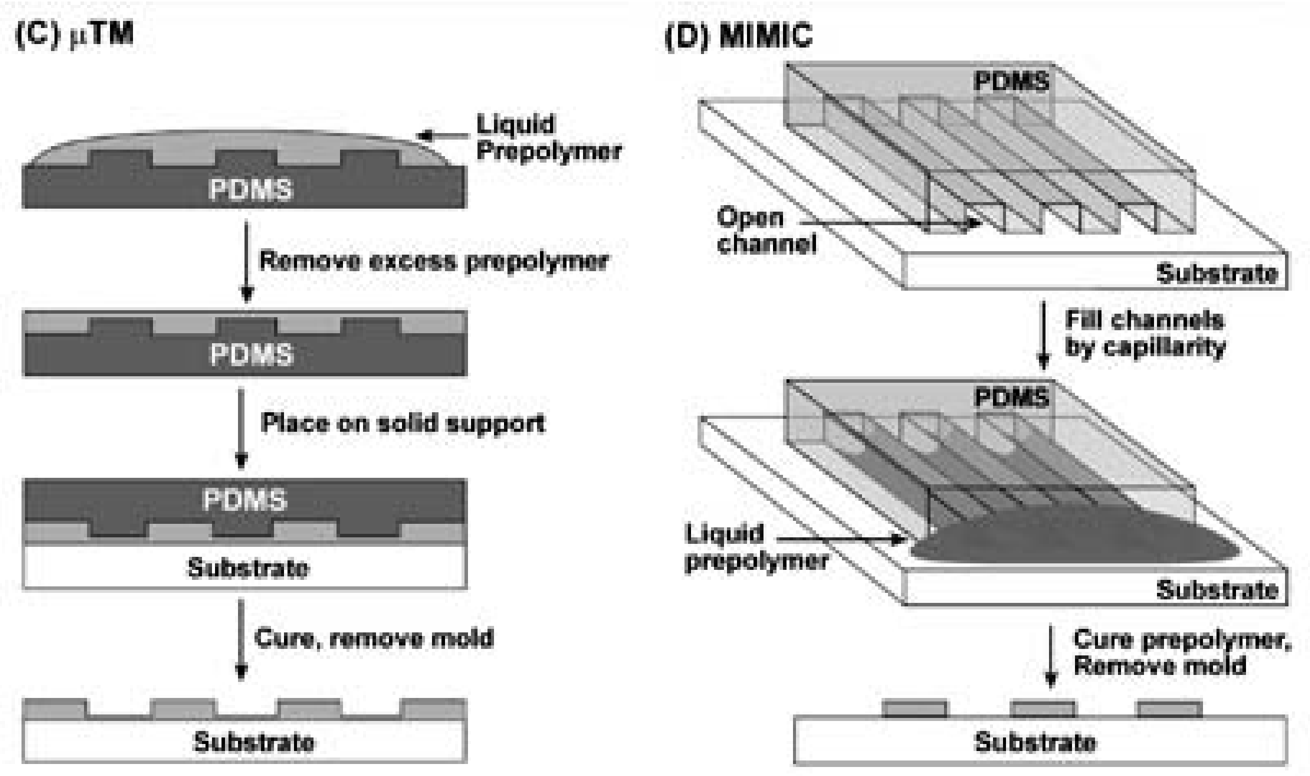
RM- replica molding

SAMIM- solvent assisted microcontact molding





µTM – microtransfer molding MIMIC –micromolding in capillaries



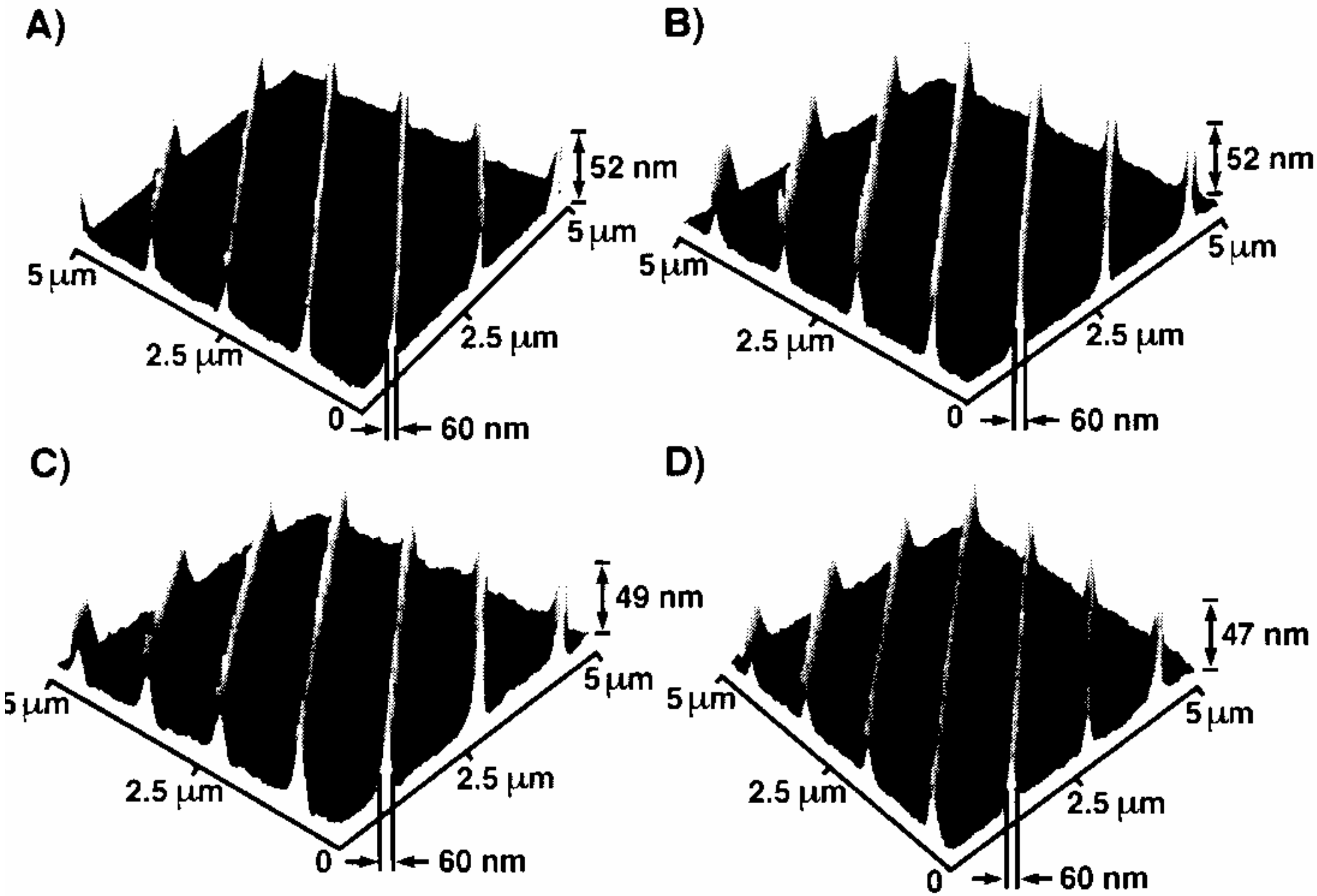


Figure 19. A, B) AFM images of gold structures on a master A) before it was used to cast PDMS molds and B) after it had been used to cast seven PDMS molds. C, D) AFM images of PU replicas produced from different PDMS molds cast from this master.[169]

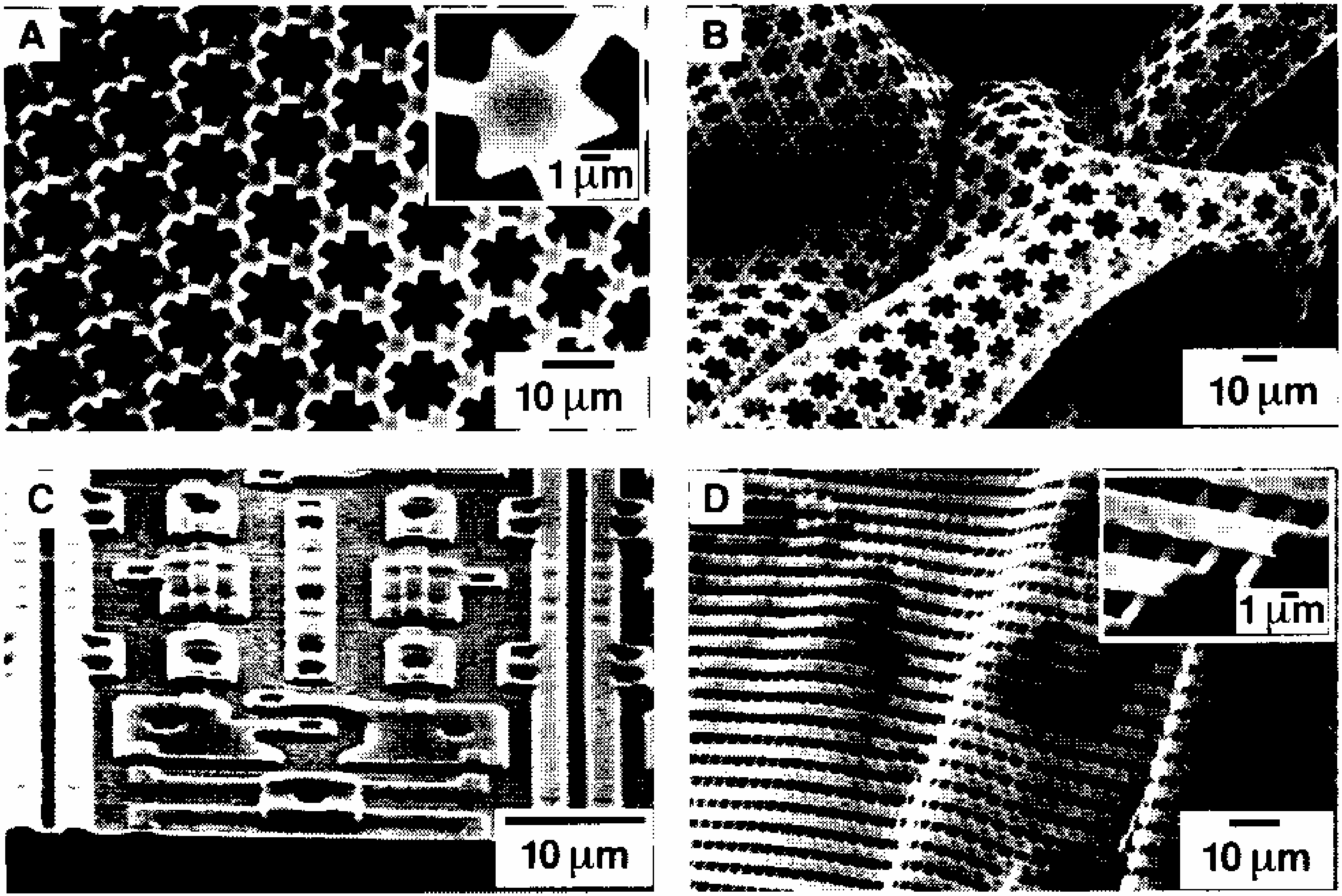
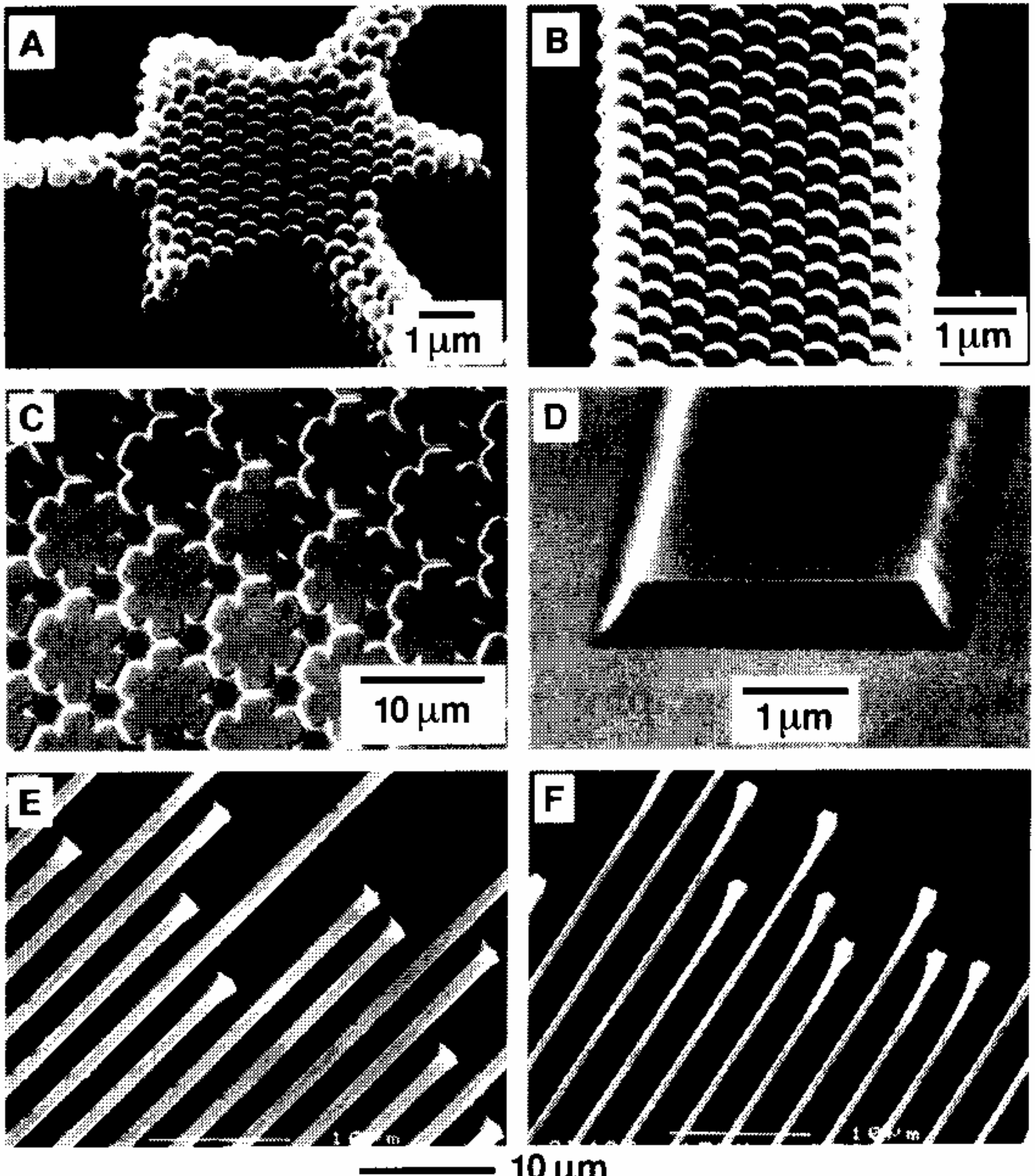


Figure 27. SEM images of polymeric microstructures fabricated by MIMIC from prepolymer of polyacrylate (A, C) and polyurethane (B, D) without solvents.[57,179] The structures in B and D are freestanding; the buckling occurred during sample preparation and demonstrated their strength.

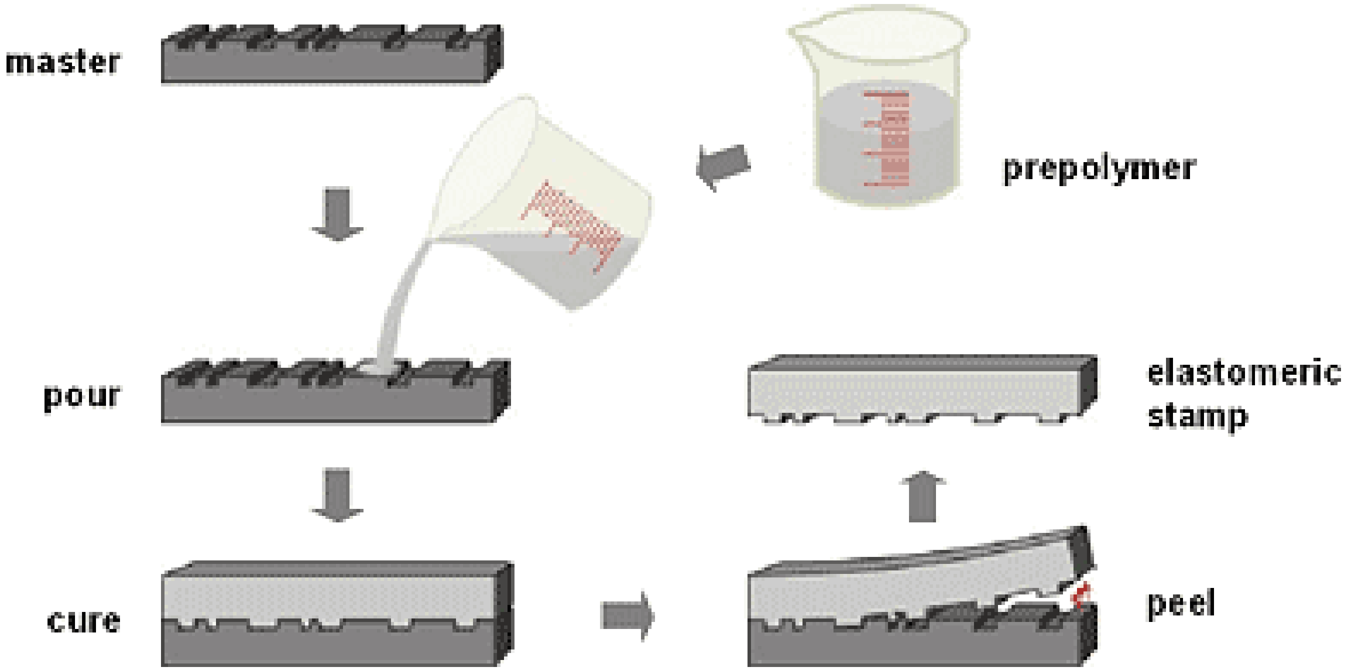

A
1 μm
B
1 μm
C
10 μm
D
1 μm
E
F
10 μm

Advantages

- convenient, inexpensive, accessible to chemists, biologists, and material scientists
- basis in self-assembly tends to minimize certain types of defects
- many soft lithographic processes are additive and minimize waste of materials
- readily adapted to rapid prototyping for feature sizes > 20 μm
- isotropic mechanical deformation of PDMS mold or stamp provides routes to complex patterns
- no diffraction limit; features as small as 30 nm have been fabricated
- nonplanar surfaces (lenses, optical fibers, and capillaries) can be used as substrates
- generation and replication of three-dimensional topologies or structures are possible
- optical transparency of the mask allows through-mask registration and processing
- good control over surface chemistry, very useful for interfacial engineering
- a broad range of materials can be used: functional polymers, sol–gel materials, colloidal materials, suspensions, solutions of salts, and precursors to carbon materials, glasses, and ceramics
- applicable to manufacturing: production of indistinguishable copies at low cost
- applicable in patterning large areas

Disadvantages and Problems

- patterns in the stamp or mold may distort due to the deformation (pairing, sagging, swelling, and shrinking) of the elastomer used
- difficulty in achieving accurate registration with elastomers (< 1 μm)
- compatibility with current itegrate-circuit processes and materials must be demonstrated
- defect levels higher than for photolithography
- μCP works well with only a limited range of surfaces; MIMIC is slow; REM, μTM, and SAMIM leave a thin film of polymer over the surface



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