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X-RAY LITHOGRAPHY AT FRASCATI: FIRST RESULTS

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Introduction.

In this paper the first results obtained using the soft X-ray beam line realized in Frascati to perform research activities in X-ray Lithography (XRL) are presented.
The spectral, geometrical and optical characteristics of the beamline are described and the main features of the X-ray masks and resists used are reported.

The Beamline

The soft X-ray beam line, called BX2L, utilizes the radiation produced by the Adone 6-equivalent full poles wiggler. Table I reports its main parameters.
The BX2L accepts 2 mrad of radiation in the horizontal plane, giving, without collimation, an horizontal beam size at the sample of about 70 mm. Its main optical element is a gold coated mirror which cuts off the hard X-rays produced by the wiggler. The shieldings and the building geometry[1] forced a reflection in the horizontal plane (s-polarization) and a grazing angle of 1.5° . This angle gives a cut off energy of about 3 keV which is satisfactory for XRL requirements.
In this preliminary stage the beamline was equipped with a 25 μm Kapton window and with the MAX-1 mask-wafer alligner supplied by Karl-Suss (Munchen, FRG).

Table I. BX2L beam line main parameters

Source	6 - poles wiggler ($B = 1.85$ T, $E_c = 2.7$ keV)
Horizontal angular acceptance	2 mrad
Beam line length	35 m
Distance Source-First mirror	12.5 m
First mirror grazing angle	1.5°
Typical energy range	0.8 - 3.0 keV

Table II reports the total power, evaluated integrating the spectral power in the 0.65 keV - 6.0 keV energy range, the power outside this range being negligible. The mirror reflectivity has been calculated by using the scattering factors reported by Henke et al.[2] and extrapolating the real part of the scattering factor up to 6 keV by means of the Kramers-Kronig integral. The mirror surface roughness has been assumed equal to 10 Å rms, as required to the manifacturer.

Table II also reports the values of the specific power (mW/mA·cm^2) and the power absorbed in a 1 μm thick poly-methyl-methacrylate (PMMA) X-ray resist.

The experimental value of the specific power obtained by means of calorimetric methods is in quite good agreement with the theoretical one.

Table II. Incident Power (P_i) and Power absorbed in 1 μm thick PMMA resist (P_a) in the 0.65 keV-6.0 keV energy range for various configurations: **1** = source; **2** = **1** + 25μm Be + one mirror refl.; **3** = **2** + 2μm Si.

Configuration Number	P_i (mW/mA·mrad)	P_i (mW/mA·cm^2)	P_a (mW/mA·mrad·μm)
1	111.0	-	-
2	10.1	1.38	-
3	7.3	1.02	0.60

Masks and Resists

Two kinds of masks have been used during the exposures.

The first kind, realized at the Fraunhofer Institut für Mikrostrukturtechnik (Berlin), consists of a 2 μm Si substrate supporting 0.8-1.0 μm thick gold patterns with smallest linewidth of 0.4 μm.

The second kind was realized at the Istituto di Elettronica dello Stato Solido (IESS) of CNR (Rome) by means of e-beam lithography and electroplating. It consists of a 4 μm BN substrate supporting 0.7 μm thick gold patterns with dimensions down to 0.15 μm.

The resists used are the following:

PMMA (high resolution, low sensitivity)

FBM-120 (low resolution, high sensitivity) - Daikin Industries, Japan.

HUNT WX-242 (low resolution, high sensitivity) - Olin Hunt, USA.

The wafers used for the exposures were prepared spinning the resist on a flat Silicon substrate, to reach the desired thickness of 0.7-1.0 μm and prebaking it.

Wafers and masks were aligned at a relative distance of 25 μm and 100 μm and put on the beam by means of the MAX-1 aligner, with an air path between the window and the mask ranging from 5 mm to 7 mm.

After the exposure the resists were developed and postbaked.

Table III reports the values used in the whole process.

Results

Figures 1 and 2 show the best results obtained. The SEM pictures have been obtained after a metallization of 200 Å of Gold. The deformation of the structure observed in fig. 1 is probably due to effects related to the high voltage (30kV) used.

Table III. Resist process

SPINNING			
Resist	PMMA	FBM-120	HUNT WX-242
Rev.(RPM)	2200	500	4000
Time (s)	40	30	60
Temperature (°C)	22-24	22-24	22-24
Thickness (µm)	1.00	1.00	1.00
PREBAKE (in air)			
Temperature (°C)	150	140	100
Time (min)	30	30	30
EXPOSURE			
Dose (mA*min)	1500	120	200
DEVELOPMENT			
Developer	MIBK/IPA 1/1	MIBK/IPA 1/125	LSI/DI 1/1
Temperature (°C)	22	22	22
Time (s)	60	120	120
Rinse	IPA	IPA	DI water
POSTBAKE (in air)			
Temperature (° C)	100	55	100
Time (min)	30	30	30

Fig.1. Replica of a 0.15 µm wide structure on PMMA resist.

Single structures of 0.15 µm were replicated on PMMA with a quite good aspect ratio and periodic structures with 0.2 µm linewidth were also obtained.
Future programs will be devoted to the optimization of the processes and materials (resists and masks) and to the replica of more complex patterns.

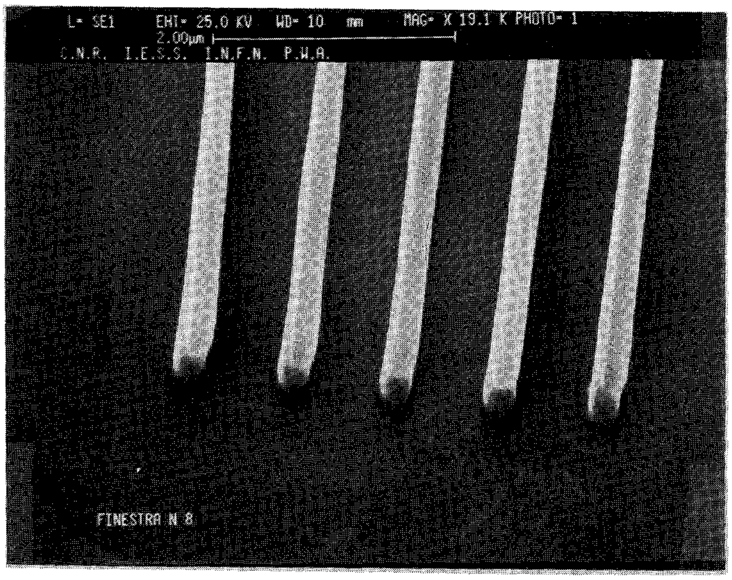

Fig. 2. Replica of a perodic structure - 0.25 µm line/0.65 µm space - on PMMA resist

References

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