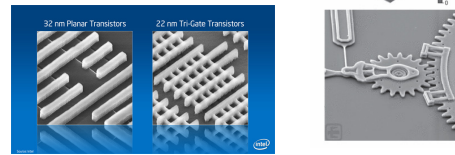


Criação de Padrões em Superfícies

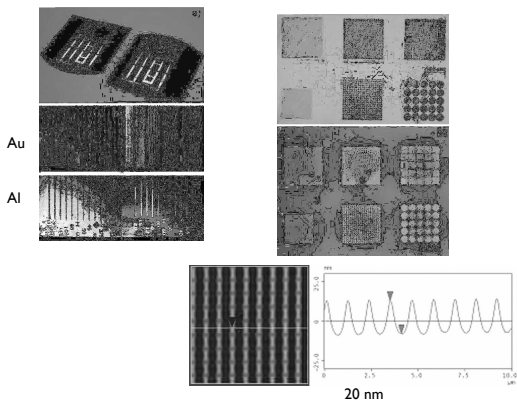
1

Litografia

- Técnica desenvolvida na antiguidade
- Aprimorada pela indústria eletrônica de semicondutores (circuitos integrados)
 - Construindo padrões em filmes finos
 - Metais
 - Dieletricos
 - Semicondutores



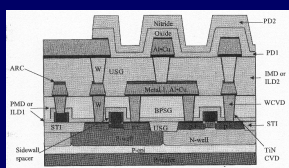
Metalizadas



Tipos de litografia

- Litografia ótica;
- Litografia de feixe de elétrons;
- Litografia por “caneta tinteiro” (dip-pen lithography) (AFM)
- Litografia de feixe de íons;
- Litografia de Raio-X;
- Litografia de partículas neutras;
- **Litografia de nano-impressão;**

Variados Tipos de Filmes Finos Utilizados na Fabricação de CIs.

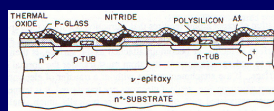


- PD – passivation dielectric
- ILD – interlayer dielectric
- IMD – intermetal dielectric
- PMD – premetal dielectric
- USG – undoped silicate glass
- BPSG – borophosphosilicate glass
- ARC – antireflection coating

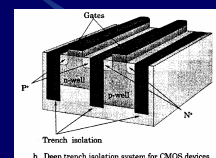
Aplicação de filmes finos dielétricos em circuitos CMOS.

Toshiaki Doi
FEEC e CCS/UNICAMP

Outros Exemplos:



Nitretos e si-poli



Dielétrico para isolação de 2 dispositivos

- Alguns filmes são usados temporariamente como camada de máscara, enquanto que outros filmes tornam partes do circuito sendo fabricado.

Toshiaki Doi
FEEC e CCS/UNICAMP

Integrando eletrônica e óptica:

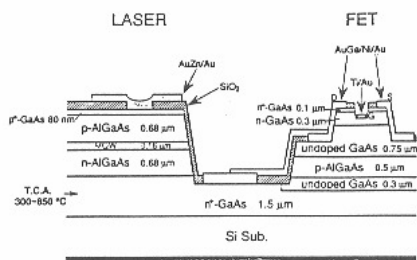


Figure 16. Schematic cross section of a laser diode, and depletion mode FET, monolithically integrated on a Si substrate. [Reprinted by permission, from Photonics Technol. Lett., 4:613 (1992)]

Litografia

Foto-litografia

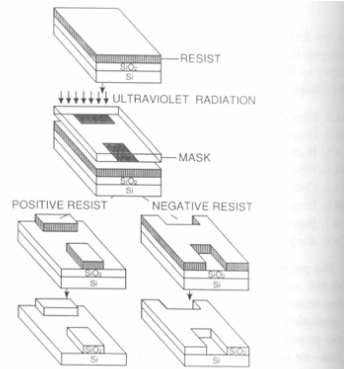
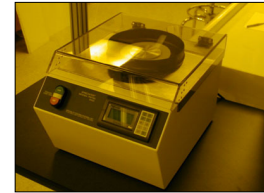


Figure 14-1. Schematic of the lithographic process for pattern transfer from mask to film. Both positive and negative resist behavior is illustrated.

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“Spinner” usado em spin coating

Lab. de Materiais Magnéticos e Supercondutores (Prof. Paulo Noronha Lisboa Filho)

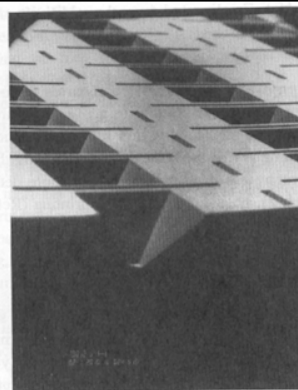


Spin-Coating

(Caso Morilla - LMMS/Uespp)

Exemplo : estrutura montada usando foto-litografia e etching seletivo

Escala: fundo da pirâmide 100µm
Base da pirâmide ~ 1mm



SEM micrograph of optical microassembly. (Courtesy of L. F. Thompson, AT&T Laboratories).

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Exemplo : estrutura montada usando foto-litografia e etching a plasma

escala (barra) = 1µm.

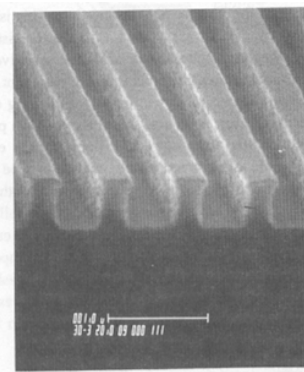
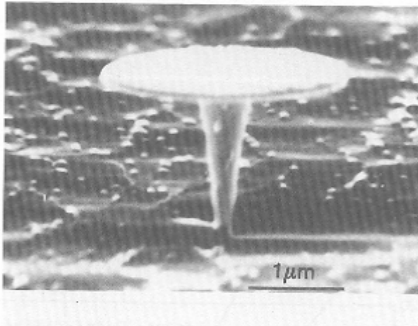


Figure 14-2. SEM micrograph of reactive plasma-etched pattern in photoresist revealing development of submicron features. (Courtesy of L. F. Thompson, AT&T Laboratories).

Etching seletivo:
Micro-cavidade laser



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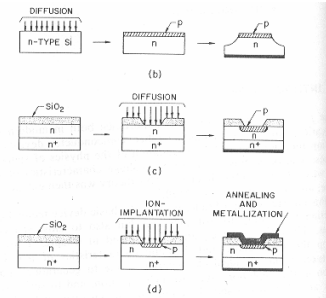


Fig. 1 Some device fabrication methods. (a) Alloyed junction. (b) Diffused junction. (c) Diffused planar junction on epitaxial substrate. (d) Ion implantation.

Receita de
corrosão em
solução
aquosa

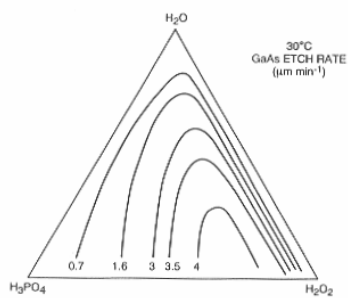


Figure 4. Isoetch rate curves for GaAs at 30°C in $H_3PO_4/H_2O_2/H_2O$ solutions (after Ref. 3).

Table 1. Wet Chemical Etch Mixtures for GaAs

Mixture	Comments
$H_2SO_4/H_2O_2/H_2O$	etch rate up to $5 \mu m \cdot min^{-1}$ for low dilution
$HNO_3/H_2O_2/H_2O$	etch rate up to $7 \mu m \cdot min^{-1}$ for low dilution
$HCl/H_2O_2/H_2O$	HNO_3 may be substituted for H_2O_2 , and methanol substituted for H_2O .
$H_3PO_4/H_2O_2/H_2O$	ethanol or methanol may be substituted for H_2O
$CH_3COOH/HNO_3/H_2O_2$	HCl often used in place of H_2O_2 .
$NH_4OH/H_2O_2/H_2O$	Peroxide-ammonia (PA) etch, common in device fabrication
HNO_3/HF	rapid etch usually diluted with H_2O .
$KI/I_2/H_2O$	selective for AlGaAs at low pH
$K_3Fe(CN)_6/K_4Fe(CN)_6$	can be made selective for GaAs or AlGaAs (18)

Uso de Plasmas no Processamento de Materiais

- Plasma Etch (corrosão a plasma)
- "Dry etch" (corrosão seca)

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Etching

Taxa de corrosão

Padrões de corrosão

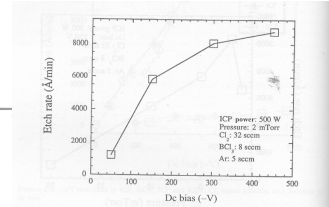


Figure 2.6. GaN etch rates as a function of dc bias in an ICP-generated $\text{BCl}_3\text{-Cl}_2\text{-Ar}$ plasma at 32 sccm Cl_2 , 8 sccm BCl_3 , 5 sccm Ar, 500 W ICP source power, 2 mTorr pressure and 10°C electrode temperature

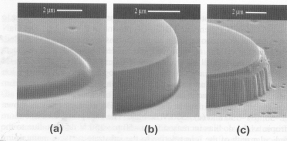


Figure 2.7. SEM micrographs for GaN etched at (a) -50, (b) -150, and (c) -300 V dc bias. ICP etch conditions were 23 sccm Cl_2 , 8 sccm BCl_3 , 5 sccm Ar, 500 W ICP source power, 2 mTorr pressure and 10°C electrode temperature

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Plasma Etching Padrões de superfície

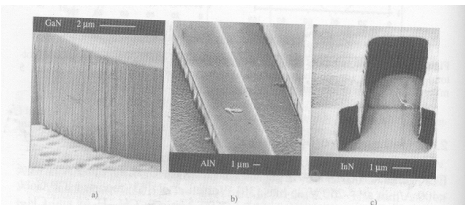


Figure 2.21. SEM micrographs of (a) GaN, (b) AlN, and (c) InN etched in Cl_2 -based ICP plasmas

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Dry Etching of Gallium Nitride and Related Materials

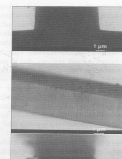


Figure 2.45. SEM micrograph of dry-etched GaN feature

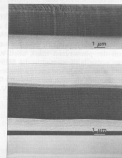


Figure 2.46. SEM micrographs of features etched into GaN at high (top) or moderate (bottom) ion energy

Padrões no GaN

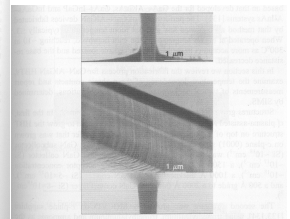
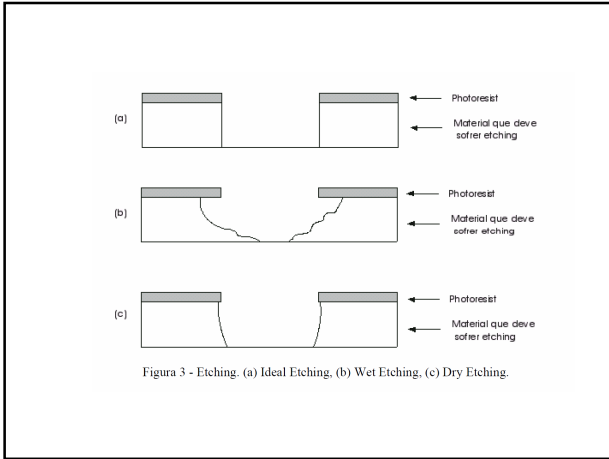


Figure 2.47. SEM micrographs of dry etched GaN-InGaN-GaN ridge waveguide laser structure

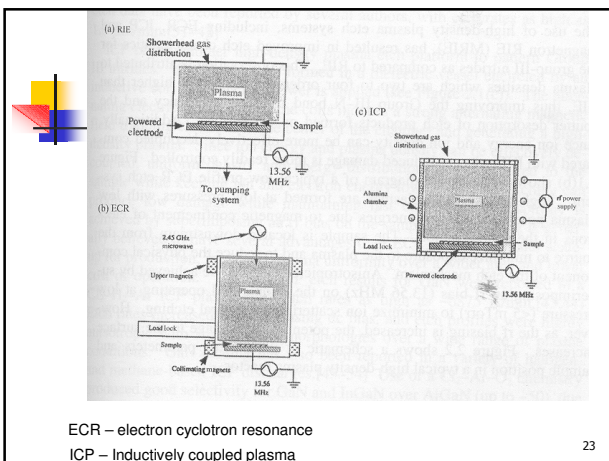
20



Plasma Etch (dry etching)

- Como fazer?

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124 Dry Etching of Gallium Nitride and Related Materials

Table 2.2. Summary of etch rate results for GaN, AlN and InN with different plasma chemistries in different techniques

Gas chemistry	Etching technique	Etch rate (nm/min) at given bias					
		GaN		AlN		InN	
SiCl ₄ /Ar/He/SF ₆	RIE	55	-400 V (118)	-	-	-	-
BCl ₃	RIE	103	-330 V (26)	-	-	-	-
HBr/Ar/H ₂	RIE	60	-800 V (27)	-	-	-	-
CHF ₃ -C ₂ F ₄	RIE	43	500 V (28)	2	2	2	2
SiF ₄	RIE	17	-800 V (27)	-	-	-	-
CHF ₃ -C ₂ F ₄	RIE	68	-500 V (28)	-	-	-	-
BCl ₃ /Ar	ECR	91	-200 V (29)	19	-250 V (29)	17	-300 V (29)
CH ₂ F ₂ -Ar	ECR	20	-250 V (29)	18	-300 V (29)	18	-300 V (29)
CH ₂ H ₂ -Ar	ECR	40	-250 V (30)	2.5	-300 V (29)	10	-300 V (29)
Cl ₂ -H ₂ -Ar	ECR	200	-180 V (32)	110	-150 V (32)	150	-180 V (32)
SiCl ₄ -Ar	ECR	92	-200 V (33)	-	-	-	-
H ₂ -H ₂	ECR	110	-150 V (35)	120	-150 V (35)	100	-150 V (35)
HBr-H ₂	ECR	70	-150 V (35)	65	-150 V (35)	13	-150 V (35)
Br ₂ -Ar	ECR	1300	-275 V (34)	200	-275 V (34)	1100	-275 V (34)
HBr-Ar	ECR	300	-170 V (67)	160	-170 V (67)	325	-170 V (67)
BCl ₃	MBE	350	-100 (37)	125	-100 (35)	100	-100 (35)
Cl ₂ -H ₂ -Ar	ICP	608	-250 V (44)	-	-	-	-
Cl ₂ -Ar	ICP	980	-450 V (53)	670	-450 V (53)	130	-100 V (44)
Cl ₂ -N ₂	ICP	65	-100 V (48)	39	-100 V (48)	30	-100 V (44)
BBr ₃	ICP	150	-380 (49)	50	-200 (49)	200	-380 (49)
Br ₂	ICP	300	-178 (49)	100	-178 (49)	200	-240 (49)
ICl	ICP	30	-300 (49)	30	-300 (49)	600	-300 (49)
Br ₂	ICP	20	-300 (49)	30	-300 (49)	600	-300 (49)
Ar ion	ICP	110	500 eV (51)	28	500 eV (51)	61	500 eV (51)
Cl ₂ (Ar ion)	ICP	210	500 eV (59)	62	500 eV (59)	-	-
BrCl (Ar ion)	ICP	180	500 eV (58)	-	-	-	-
Cl ₂	RIE	150	800 eV (50)	-	-	-	-
BrCl	RIE	130	500 eV (50)	-	-	-	-
Cl ₂ -Ar	RIE	50	-400 (50)	50	-400 (50)	80	-400 (50)
BrCl	RIE	1040-2040	080	-	-	-	-
H ₂ -Cl ₂	RF	30-7	1-15 eV (61, 62)	-	-	-	-

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Perguntas até aqui?

- ◆ Na sequência => Implantação Iônica

Prof. José Humberto Dias da Silva
POSMAT/Unesp-Bauru

Caracterização

- Espectroscopia de Fotoelétrons Excitados por raios X (XPS)
- MEV
- AFM
- Refletância (espessura dos filmes)

• Corrosão

- Corrosão a plasma de O_2 em 180 W
- Até o wafer se Si ser exposto

• Deposição de metais

- metais evaporado a vácuo (Au e Al)

• Remoção Lif-off da camada de resist

- por sonicação em metanol quente