

---

# O mundo dos materiais

---

Capítulo 1

---

# Introdução

---

- ❖ Idade da pedra, 2,5 milhões de anos atrás: pedaços de rochas
- ❖ Idade do bronze, 2000 - 1000 anos a.C.: ligas metálicas (cobre e estanho) começaram a serem utilizadas para fazer ferramentas
- ❖ Idade do ferro, 1000 - 1 ano a.C.: ferro passa a ser usado
- ❖ Além dos metais, cerâmicas e vidros também foram utilizados
- ❖ Hoje: idade do plástico? do silício?





---

# Classificação dos Materiais

---

- ❖ Metais
- ❖ Cerâmicas
- ❖ Vidros
- ❖ Polímeros
- ❖ Compósitos
- ❖ Semicondutores

# Metais

---

- ❖ Aço, ferro, cobre, zinco, ouro, prata, bronze, ...
- ❖ Características: forte, resistente, moldável (dúctil)
- ❖ Formam rede cristalina.
- ❖ Brilhante (alta reflexão especular)
- ❖ Bom condutor de eletricidade
- ❖ Bom condutor de calor
- ❖ Exemplo de aplicação: pontes!!



# Metais

The periodic table is color-coded to categorize elements:

- Metal:** Shown in blue-grey boxes.
- Metalloid:** Shown in light green boxes.
- Nonmetal:** Shown in gold boxes.

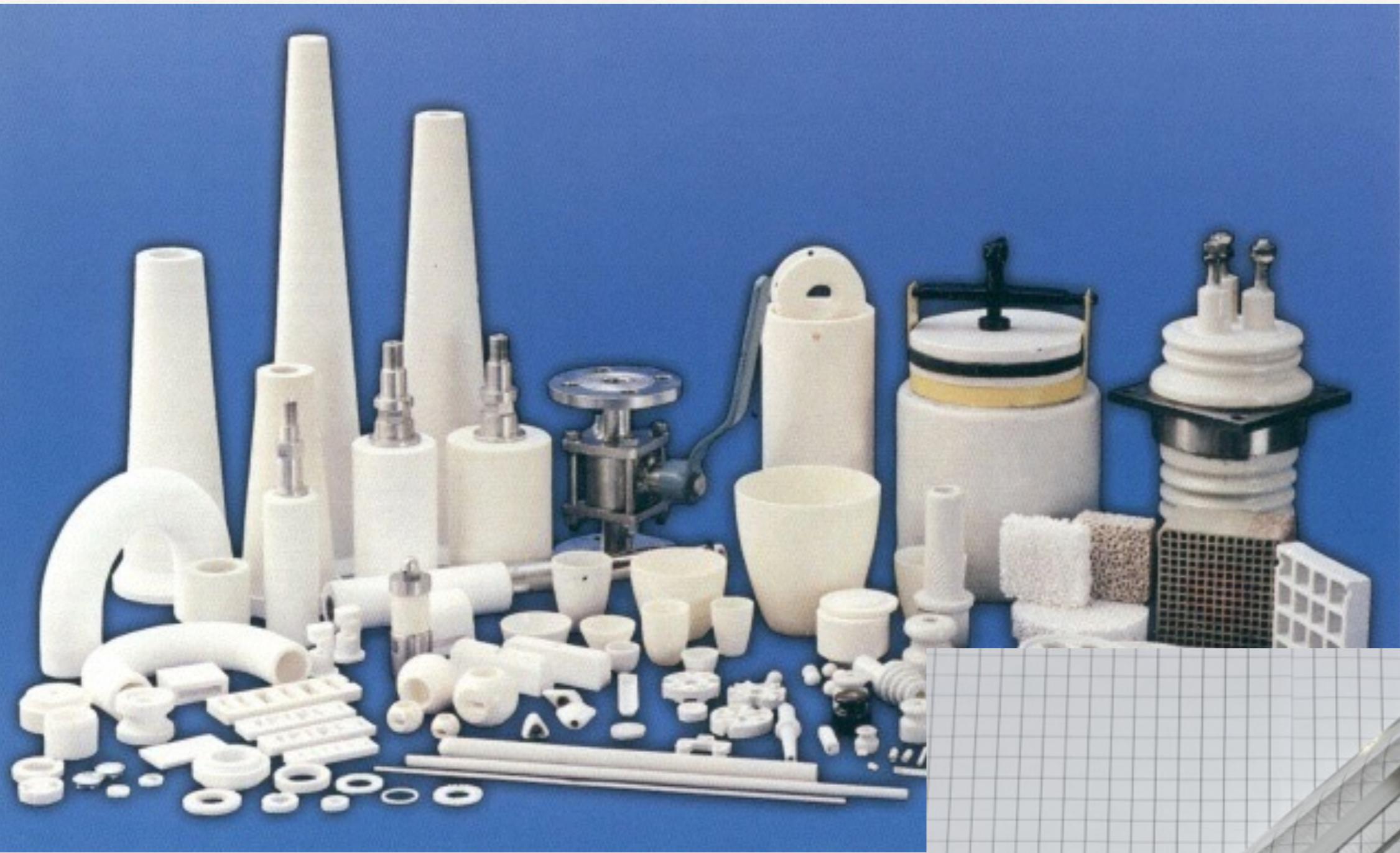
Key features of the table include:

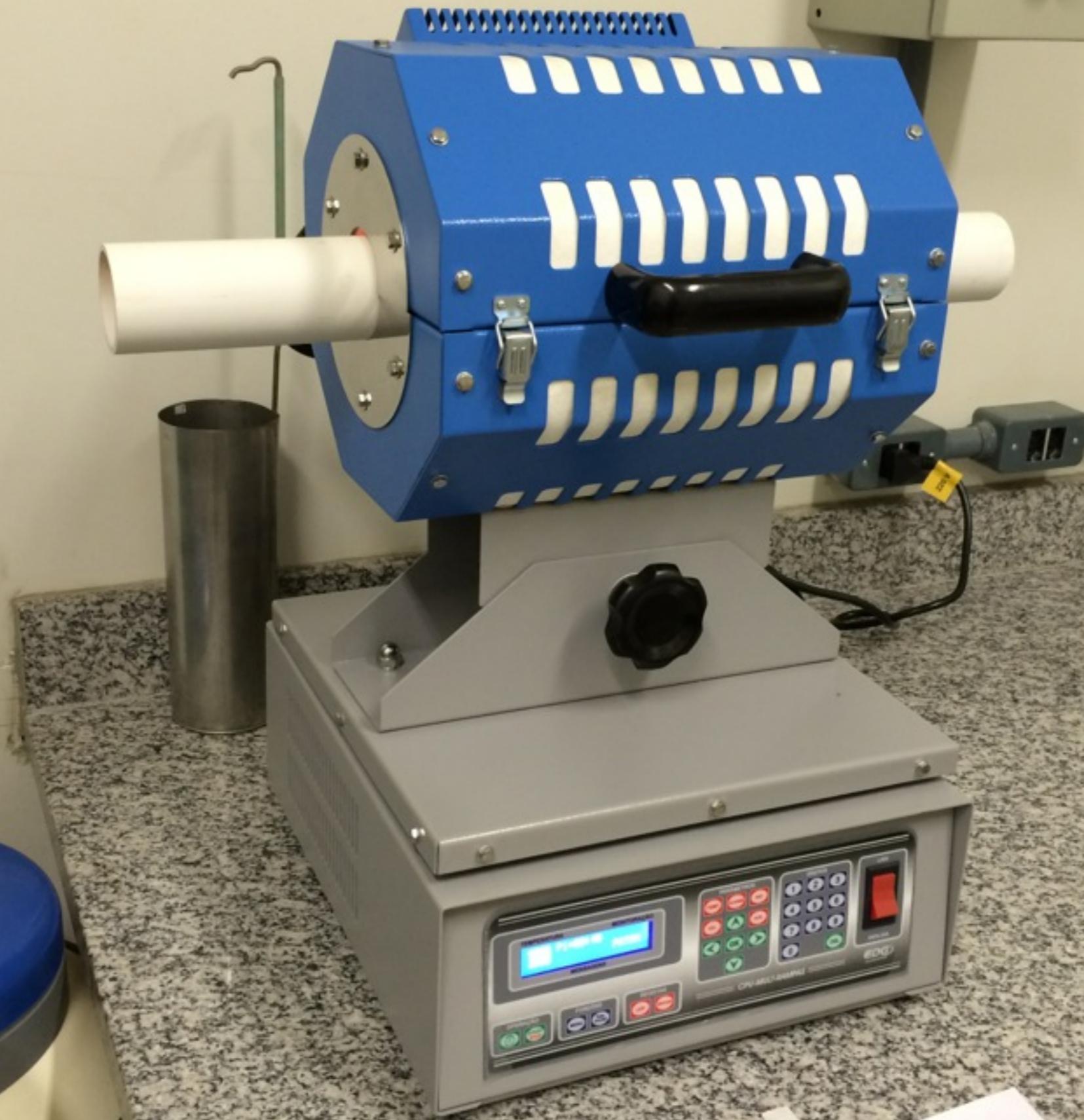
- Groups:** Groups 13 through 18 are explicitly labeled at the top right.
- Periods:** Period numbers 1 through 7 are indicated above the table.
- Transition Metals:** A vertical column of blue-grey boxes is located between groups 3 and 4.
- Lanthanides and Actinides:** Two rows of blue-grey boxes are located below the main table, corresponding to periods 5 and 6 respectively.

1																				18															
1	H	2																	He																
3	Li	4	Be																																
11	Na	12	Mg																																
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
55	Cs	56	Ba	57-71		72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
87	Fr	88	Ra	89-103		104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Uut	114	Fl	115	Uup	116	Lv	117	Uus	118	Uuo
57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu						
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr						

# Cerâmicas

- ❖ Formam rede cristalina.
- ❖ Alumínio (Al) é um metal.
- ❖ Óxidos de alumínio,  $\text{Al}_2\text{O}_3$  por exemplo, é uma cerâmica.
- ❖ Diferenças: não enferruja, alto ponto de fusão, baixa ductilidade.
- ❖ Outras cerâmicas: óxidos de magnésio, silício (silicatos), que incluem argila e semelhantes.
- ❖ Regra geral: cerâmicas são feitas de um metal e um não metal (C, N, O, P e S)

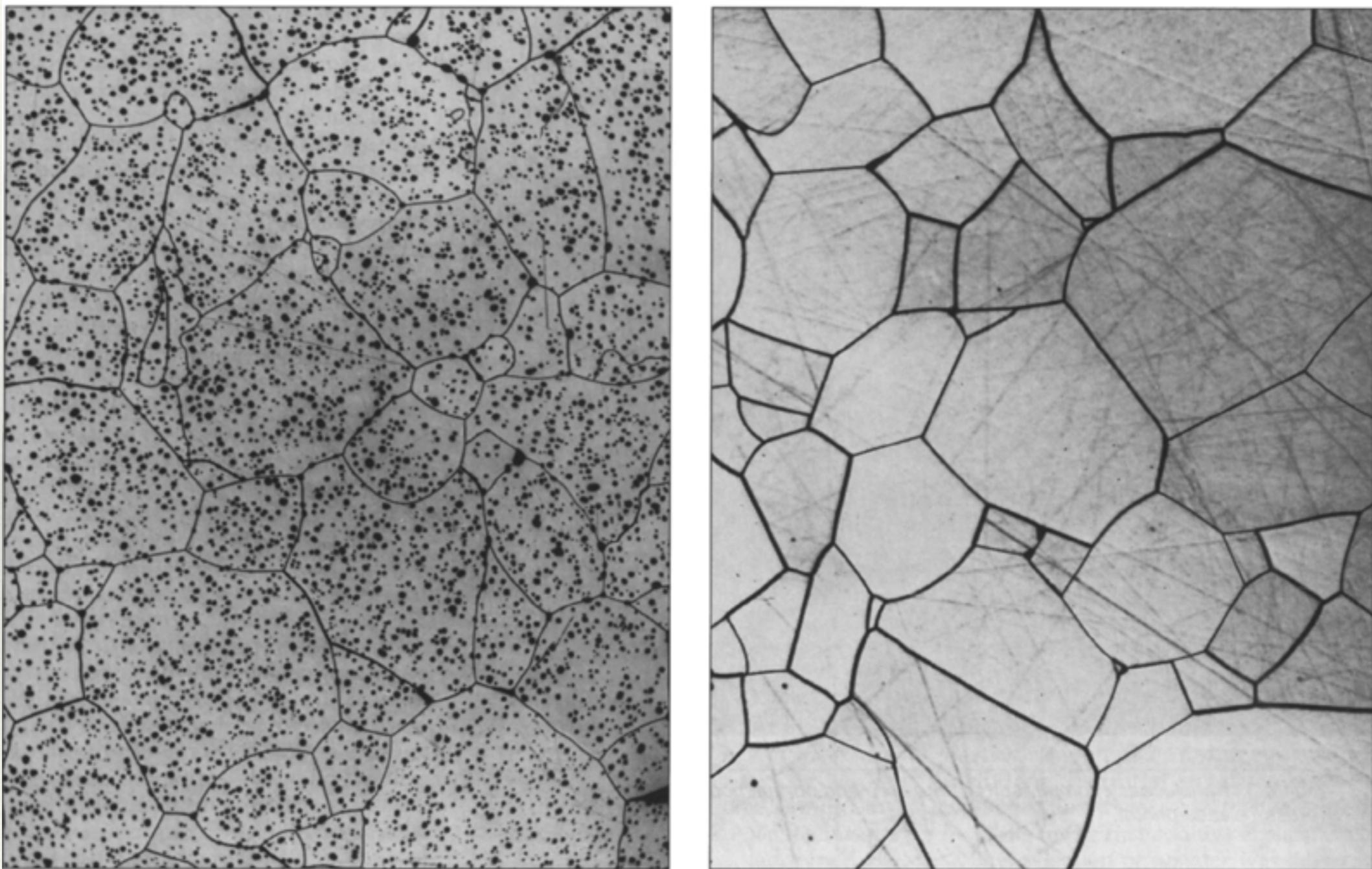




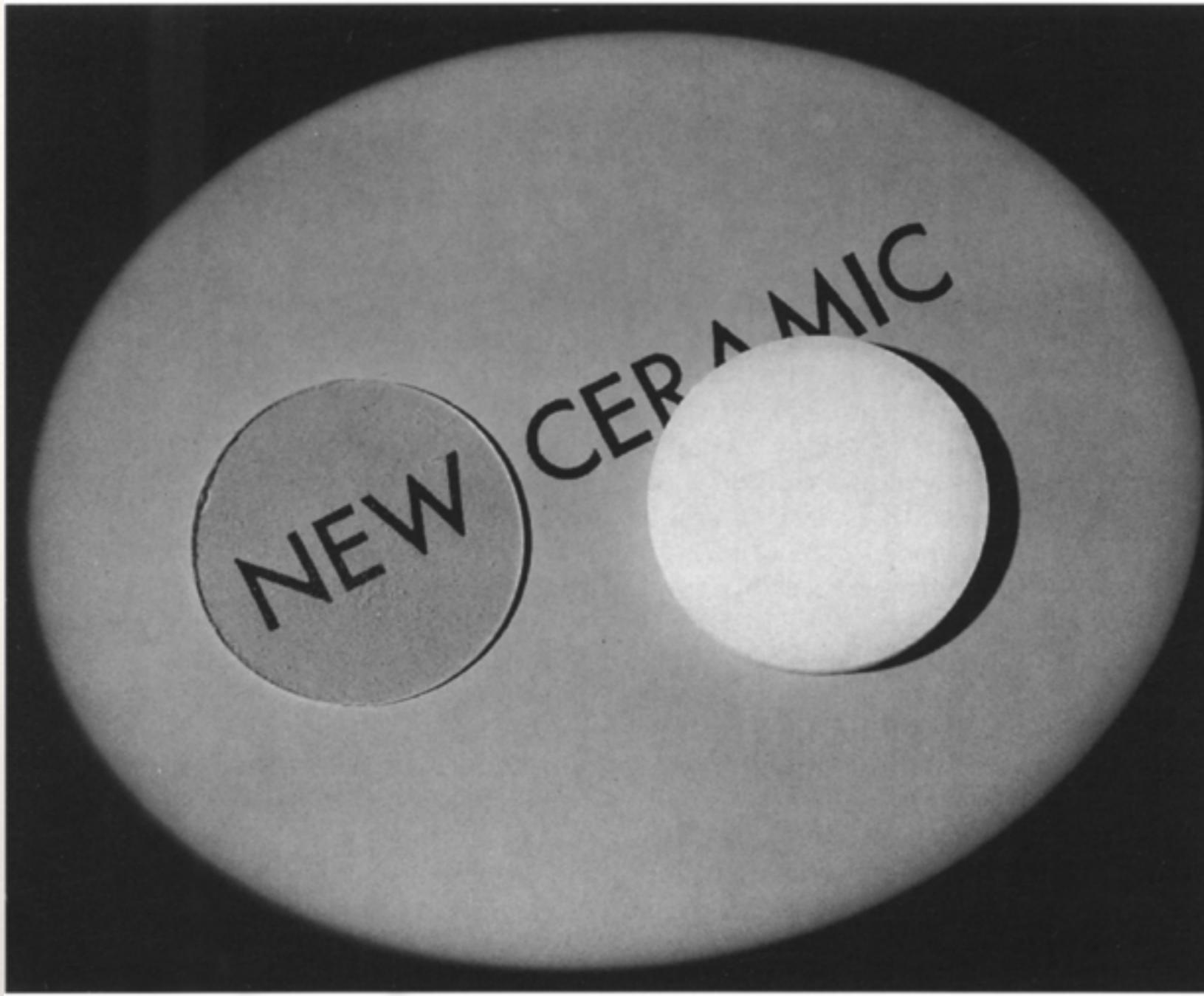
VIGADO!

## Lucalox® Alumina: The Ceramic That Revolutionized Outdoor Lighting

J.E. Burke



*Figure 4. Comparison of microstructures of porous, sintered alumina, sintered without MgO addition (left) and the pore-free ceramic in which a MgO addition prevented discontinuous grain growth (right). Original magnification is 250X. (Press release photo.)*

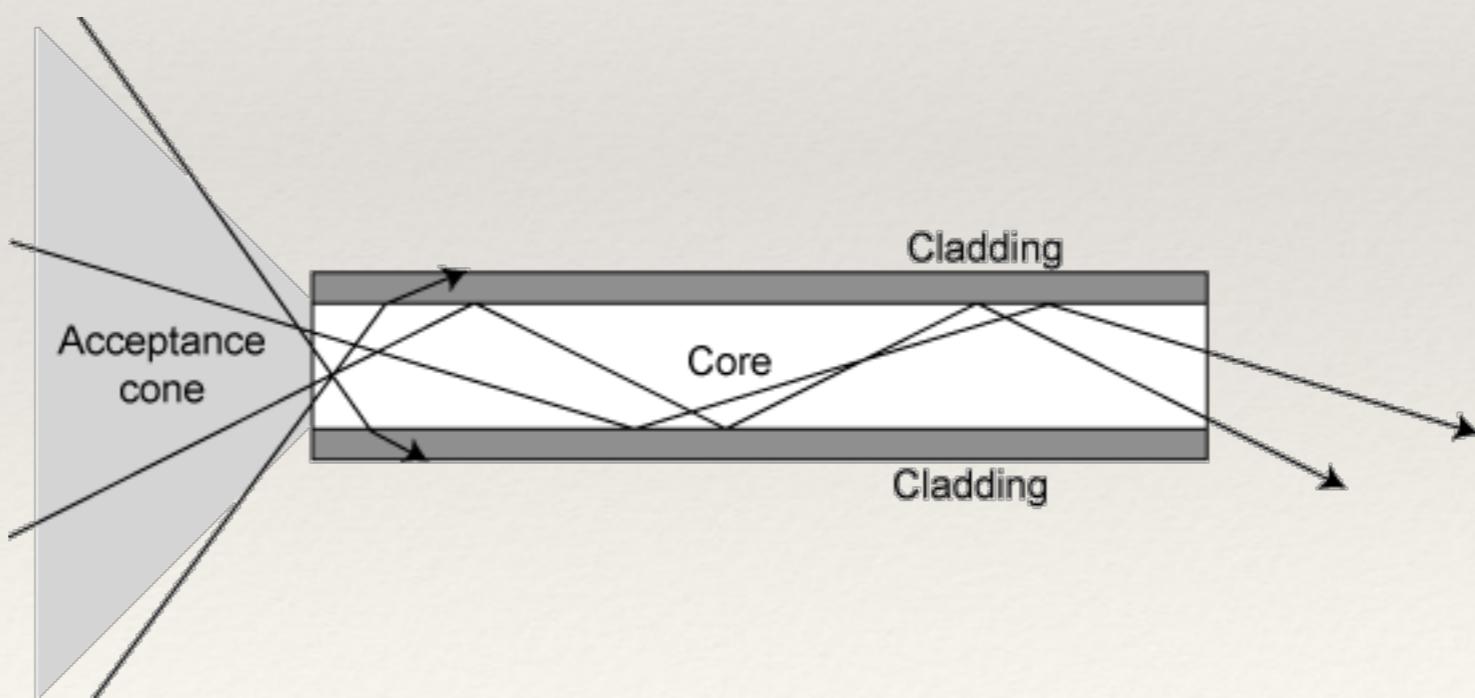
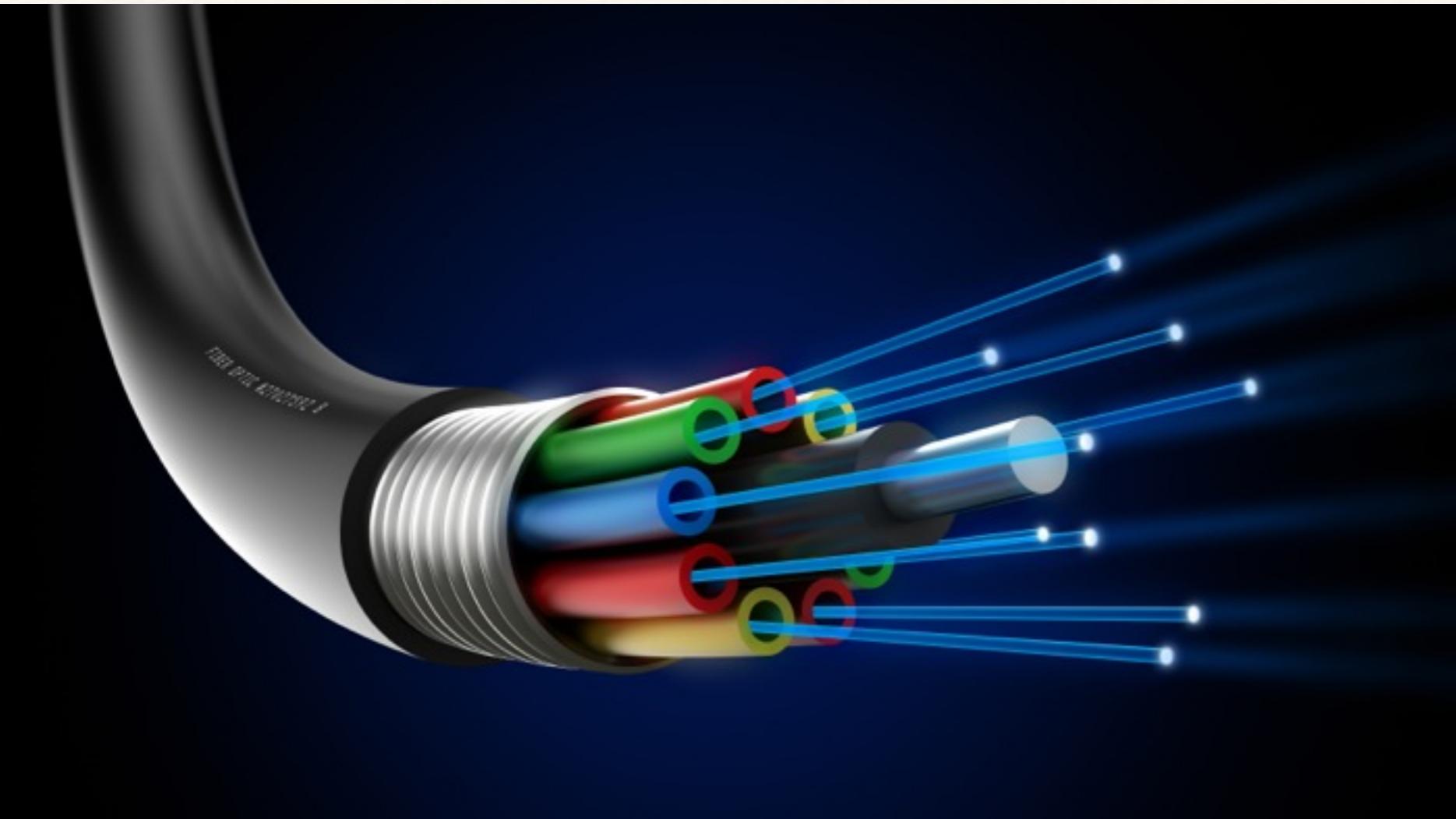




# Vidros

---

- ❖ Ao contrários de metais e cerâmicas, vidros não são cristalinos.
- ❖ Podem ser produzidos a partir de materiais cerâmicos.
- ❖ A maioria dos vidros é a base de sílica ( $\text{SiO}_2$ ).
- ❖ Não são dúcteis.
- ❖ Alta transmissão óptica
- ❖ Alta estabilidade química.



# Electromagnetic mode simulation on optical fiber coupling with transversal misalignment



Rafael Grisotto e Souza, P. F. Gomes

Campus de Jataí, Universidade Federal de Goiás, Jataí.

Felipe Beltrán Mejía

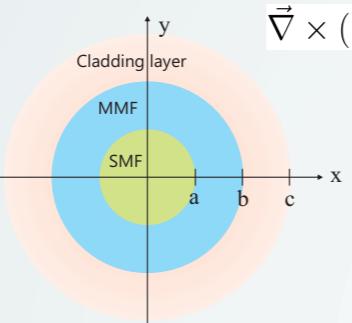
Instituto de Física "Gleb Wataghin", Universidade Estadual de Campinas, Campinas.

José Luiz González Arango

Departamento de Física y Geología, Universidad de Pamplona, Pamplona, Colômbia.

## Introduction

- In this work we calculate the electromagnetic mode distribution in different types of optical fibers. We have solved numerically the vectorial wave equation (eq. 1) for the complex electric vector.
- The input is the refraction index  $n(x,y)$  on the transversal section of the fiber.
- The axis of the fiber is assumed to be the  $z$  axis. We calculate the mode on the  $xy$  plane.



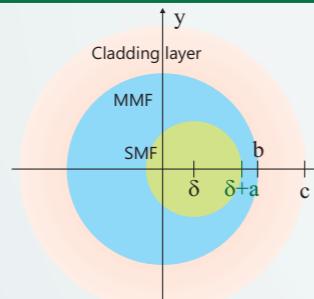
$$\nabla \times (\vec{\nabla} \times \vec{E}) - k_0^2 n^2 \vec{E} = 0 \quad \text{eq. 1}$$

$$n_s(r) = \begin{cases} n_1 & \text{if } 0 \leq r \leq a \\ n_0 & \text{if } a \leq r \leq c \end{cases} \quad \text{eq. 2}$$

$$n_m(r) = \begin{cases} n_2(r) & \text{if } 0 \leq r \leq b \\ n_0 & \text{if } b \leq r \leq c \end{cases} \quad \text{eq. 3}$$

Fig. 1: Geometry of the fiber  $n_0 = n_1 \sqrt{1 - 2\Delta}$   $n_2(r) = n_1 \sqrt{1 - 2\Delta} \frac{r^2}{b^2}$

- The geometry is depicted on Figure 1 and the parameters are described on table 1.
- $n_s$  and  $n_m$  are the refraction index of the SMF (fiber 1) and the MMF (fiber 2).  $r$  is the polar coordinate:  $r^2 = x^2 + y^2$
- The solutions for the electric fields are:  $\vec{E}_1$  and  $\vec{E}_2$  for the fundamental mode on the SMF and on the MMF,  $\vec{E}_{22}$  for the 1st excited simmetric mode on the MMF.



## Problem 2: Transversal displacement

$$|\vec{E}_{22}|^2$$

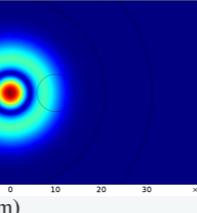


Fig. 7:  $\psi_2$  = MMF 1st excited mode.  $\delta = 8 \mu\text{m}$ .

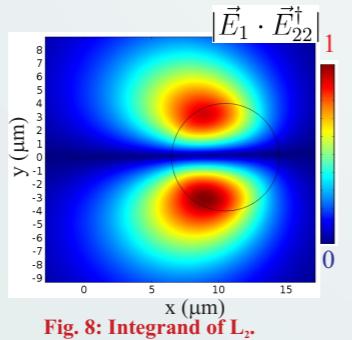


Fig. 8: Integrand of  $L_2$ .

$\delta = 8 \mu\text{m}$ .

## Acknowledgements



## Problem 1: wavelength optimization

$$|\vec{E}_2|^2$$

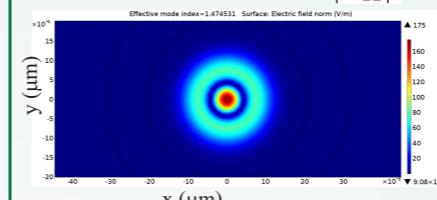


Fig. 2: SMF fundamental mode

$$|\vec{E}_{22}|^2$$

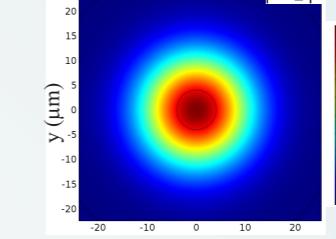


Fig. 3: MMF fundamental mode

## Fig. 4: SMF fundamental mode

$$|\vec{E}_1|^2$$

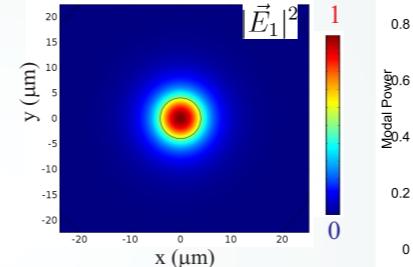


Fig. 4: SMF fundamental mode

## Fig. 5: Modal amplitude vs wavelength of the mode.

M=1 e next=1

Modal Power

Wavelength [μm]

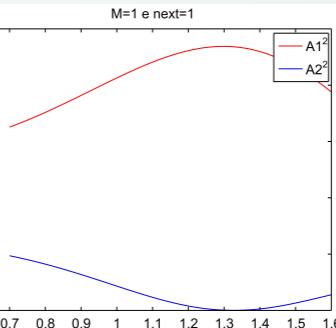


Fig. 5: Modal amplitude vs wavelength of the mode.

## Analysis

- Problem 1: transmission between fiber 1 to fiber 2 for different wavelengths.  $L_1(\lambda)$  (eq. 4) is the modal amplitude considering the fundamental mode on fiber 2 (Fig. 3), while  $L_2(\lambda)$  (eq. 5) is for the 1st excited simmetric mode on fiber 2 (Fig. 4).
- The maximum transition  $L_1(\lambda)$  is at  $\lambda = 1.1 \mu\text{m}$ , and for  $L_2(\lambda)$  is at  $\lambda = 1.4 \mu\text{m}$  (see Fig. 5). This calculus is important for a proper design of optical fiber system.

Symbol	Value
$\Delta$	0.003
$n_0$	1.402
$n_1$	1.444
$\lambda_0$	1.55 $\mu\text{m}$
$a$	4 $\mu\text{m}$
$b$	30 $\mu\text{m}$
$c$	60 $\mu\text{m}$

$$L_1 = \iint \vec{E}_1 \cdot \vec{E}_2^\dagger da \quad \text{eq. 4}$$

$$L_2 = \iint \vec{E}_1 \cdot \vec{E}_{22}^\dagger da \quad \text{eq. 5}$$

Table 1: Parameters values

- Problem 2: Transversal misalignment
- The SMF is displaced by an amount  $\delta$  from the MMF (see figure 6.)
- Again,  $L_1(\delta)$  and  $L_2(\delta)$  are the modal amplitudes, considering the fundamental and the 1st simmetric excited mode on fiber 2 (Fig. 7).
- As expected,  $L_1(\delta)$  has maximum at  $\delta = 0$ .
- $L_2(\delta)$  has maximum at  $\delta = 8 \mu\text{m}$  (Fig. 8), where the maximum of the  $E_1$  mode superposes the maximum of the  $E_2$  mode (fig. 9).

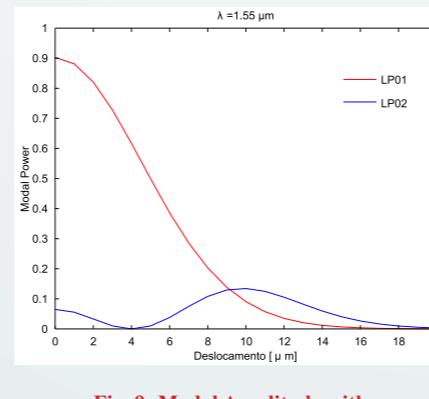


Fig. 9: Modal Amplitude with transversal misalignment.

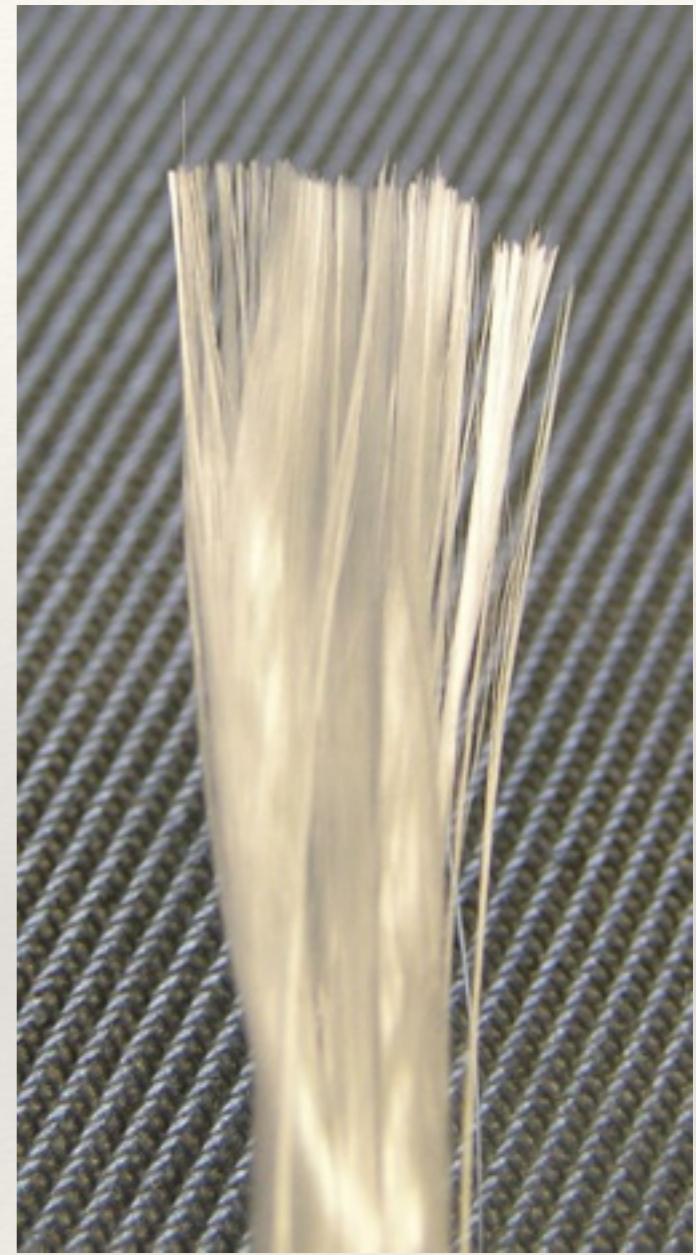
# Polímeros

- ❖ Também chamado de plástico.
- ❖ Sintéticos (não encontrados na natureza). Ramo da química orgânica.
- ❖ Mais comum: oletileno ( $C_2H_4$ ) $n$
- ❖ Em geral, feitos apenas de C e H. Elementos como oxigênio, nitrogênio, flúor, silício, etc..., são adicionados para alterar suas propriedades.
- ❖ Nylon: polihexametileno adipamida, inventado em 1935 por DuPont.
- ❖ Comparação com metal: dúctil, leve, resistente, barato, baixo ponto de fusão

# Ligaçāo Química

---

- ❖ Metais: ligação metálica
- ❖ Cerâmicas e vidros: ligação iônica
- ❖ Polímeros: ligação covalente
- ❖ Compósitos: formados por todos esses materiais
- ❖ Exemplo: fibra de vidro. Feito por fibras de vidro em uma matriz de polímero.
- ❖ Combina a resistência da fibra de vidro com a ductibilidade dos polímeros
- ❖ Kevlar: poli p-fenilenetereftalamida. Fibra de vidro melhorada.

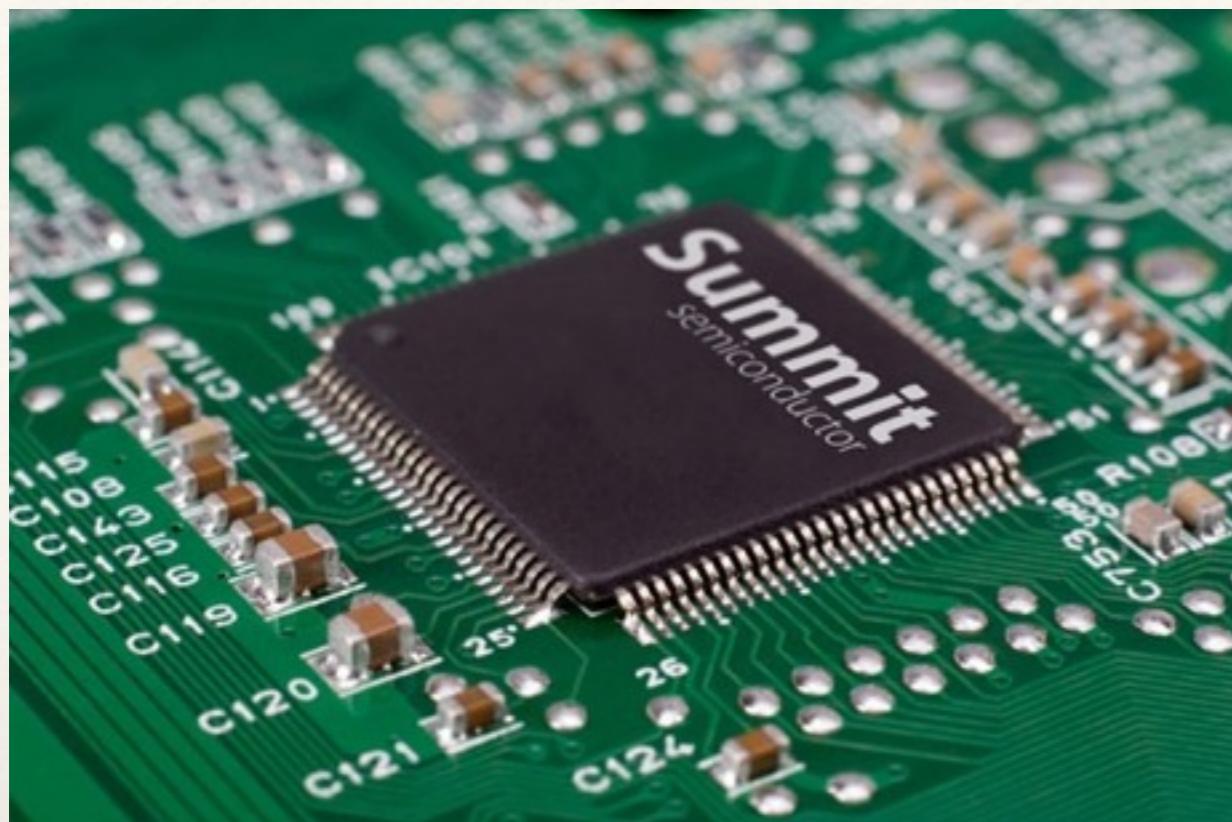


---

# Semicondutores

---

- ❖ Materiais com condutividade elétrica facilmente controlada por parâmetros externos
- ❖ Base dos dispositivos eletrônicos
- ❖ Indústria eletrônica revolucionou nosso modo de viver
- ❖ Si, Ge, GaAs, InP, InAs, etc...



VIIIA							
2	He 4.003						
5	B 10.811	6	C 12.011	7	N 14.007	8	O 15.999
IB		IIB		15	P 30.974	16	S 32.064
29	Cu 63.54	30	Zn 65.37	31	Ga 69.72	32	Ge 72.59
47	Ag 107.870	48	Cd 112.40	49	In 114.82	50	Sn 118.69
79	Au 196.967	80	Hg 200.59	81	Tl 204.37	82	Pb 207.19
						83	Bi 208.980
						84	Po (210)
						85	At (210)
						86	Rn (222)

