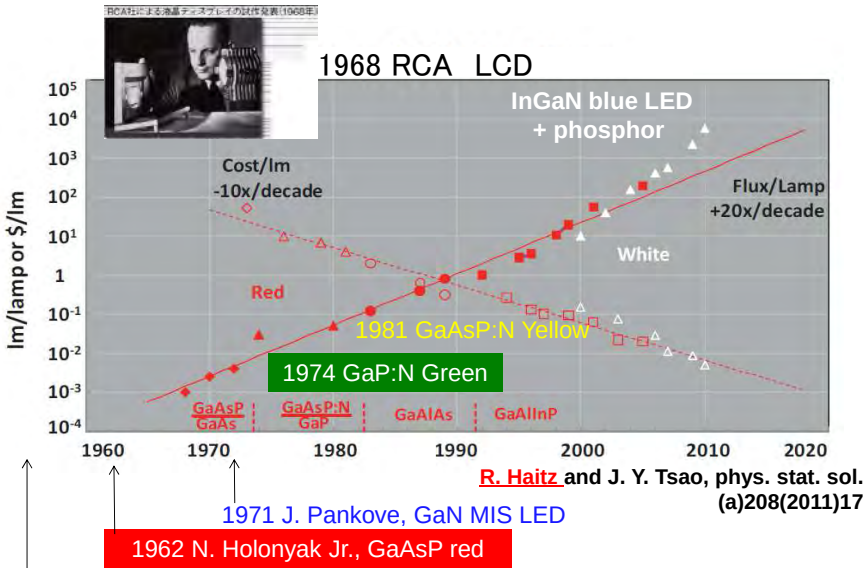
LEDの実用化および発展の歴史



1950年代～1970年代、先達のGaN研究

HVPE法によるMIS型GaN青色LED

窒化ガリウム(GaN)研究の“種”はいつ生まれたか?

Über die Kantenemission und andere Emissionen des GaN

Von H. G. Grimmeiss und H. Koelmans

Aus den Philips-Forschungslaboratorien Aachen und Eindhoven

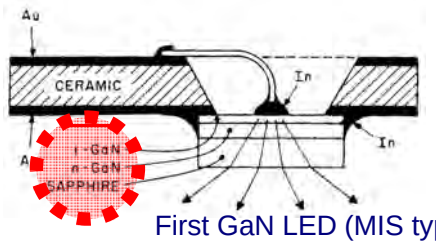
(Z. Naturforschg. 14 a, 264—271 [1959]; eingegangen am 18. Dezember 1958)

ZEITSCHRIFT FUR NATURFORSCHUNG A 14(1959)264.

56年前！

H.G. Grimmeiss, H. Koelmans & I.B. Maak, *German patent*, DBP 1 077 330 (1960).

世界初 青色LEDの萌芽



First GaN LED (MIS type)

Efficiency： 10^{-5}～3×10^{-4}

J. I. Pankove, E. A. Miller, D. Richman and J. E. Berkeyheiser: J.Lumin. 4 (1971) 63.

http://www.colorado.edu/memorybox/jacquespankove.html

Dr. Kayann Short • Farrand Academic Program, University of Colorado at Boulder • 303-492-1267 • shortk@colorado.edu

44年前

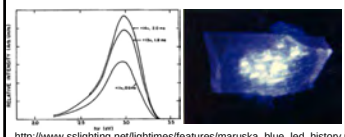
1970年代のGaN研究　早すぎた挑戦

Violet luminescence of Mg-doped GaN

H. P. Maruska, D.A. Stevenson, J. I. Pankove

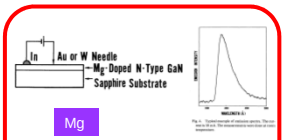
Mg

Appl. Phys. Lett., 22, 303 (1973).



http://www.sslighting.net/lightimes/features/maruska_blue_led_history.

Stanford University and RCA



Mg

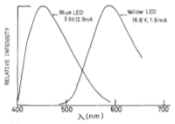
JAPAN. J. APPL. PHYS. Vol. 13 (1974), No. 8

Violet-Electroluminescence from Mg-Doped GaN Point Contact Diodes

YASUO MORIMOTO

Research Laboratory, OKI Electric Industry Co., Ltd.,

Oki Electric

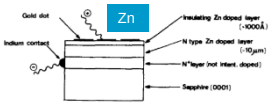


Optical Properties of GaN Light Emitting Diodes

Zn

J. Electrochem. Soc., 123 (1978)1725.

Hitachi

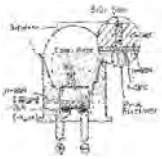


Zn

FIG. 3. Structure of the electroluminescent device.

G. Jacob and D. Bois, Appl. Phys. Lett., 30 (1977) 412.

Philips



Zn

Matsushita Research Institute, Tokyo (Panasonic)

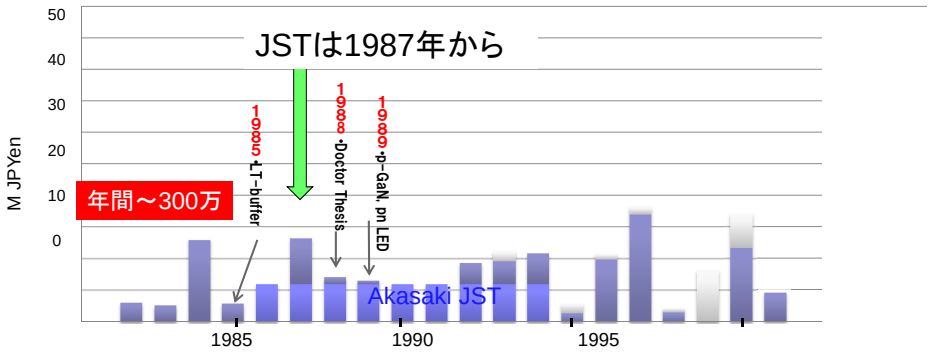
Y. Ohki, Y. Toyoda, H. Kobayashi and I. Akasaki, Intl. GaAs Symp., 479-484 (1981)

May 1981, New York

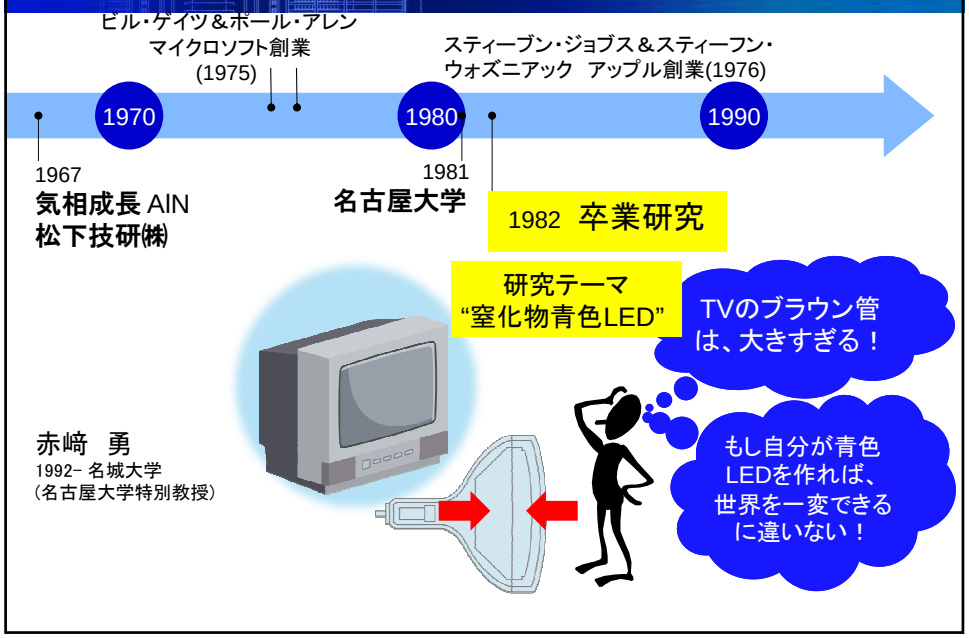
1981年　赤崎教授　松下電器㈱→名大へ

1980年代前半、名大の研究環境

赤﨑先生が名大に移った当時(80年代初頭)の研究費の状況



何故、自分は研究テーマとして青色LEDを選んだか?

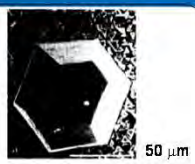


何故1970年代、青色LEDは実用化できなかったのか?

バルク単結晶

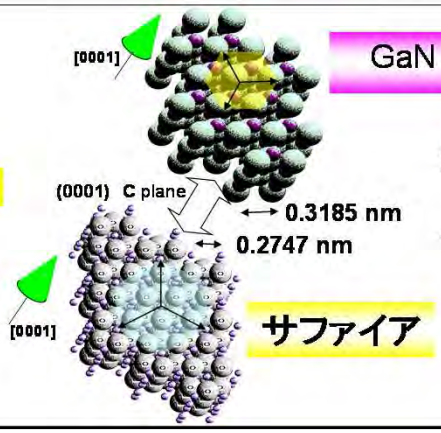
ダイヤモンド
52,000 atm
1,200℃

GaN
45,000 atm
2,530℃



J. Karpinski and S. Porowski, JCG, 66(1984)1.

薄膜結晶



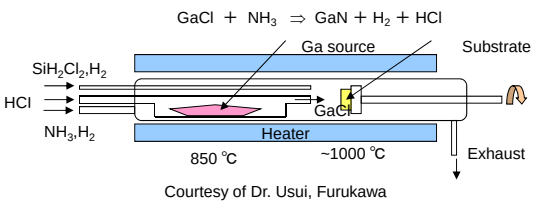
格子不整合

$$\frac{0.3185 - 0.2747}{0.2747} \approx +16\%$$

一般にヘテロエピタキシャル成長では<1%.

赤﨑教授のご慧眼

1970年代　HVPE

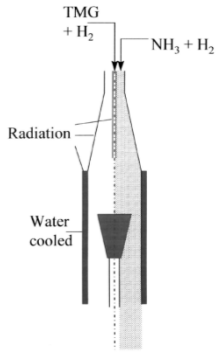


Courtesy of Dr. Usui, Furukawa

- マルチゾーン温度制御
- 副生成物　NH_4Cl
- 成長速度>50 μm/hr

HVPE: Halogen transport VPE
MOVPE: Metalorganic VPE

MOVPE



S. A. Safvi et al.,　J. Electrochem. Soc., 144(1997)1789.

- 加熱は基板サセプタのみ
- 成長速度 ～数 μm/hr

R. A. Ruehrwein, US Patent 3312570 (1961).

54年前