Vorlesung Oberflächenphysik III – Nanostrukturen

Sommersemester 2018

13. April	Graphen I
20. April	Graphen II
27. April	GF, LDOS
4. Mai	T-Matrix, Q-Corrals
11. Mai	Volumendefekte, EF
18. Mai	IEC, RKKY, QWS
25. Mai	Exkursionswoche
1. Juni	Quantentransport 1D
8 . Juni	Leitwertquantisierung
15. Juni	Q-Dots, C-Blockade,
22. Juni	Schrotrauschen
29. Juni	Spin Orbit WW
6. Juli	Tiefe Temp
13. Juli	Vertretung Dr. Gruber

Programm:

- Graphen: elektronische Eigenschaften
- Elektronenpropagation - Greensche Funktionen
- Punktdefekte auf und unter Oberfächen
- Ballistischer Transport, Leitwertquantisierung
- Schrotrauschen in Nanostrukturen
- Spin-Orbit Wechselwirkung in Festkörpern
- Erzeugung tiefer Temperaturen

Nobel Prize 2010

The Nobel Prize in Physics 2010
Andre Geim, Konstantin Novoselov

- The Nobel Prize in Physics 2010
- Nobel Prize Award Ceremony
- Andre Geim
- Konstantin Novoselov

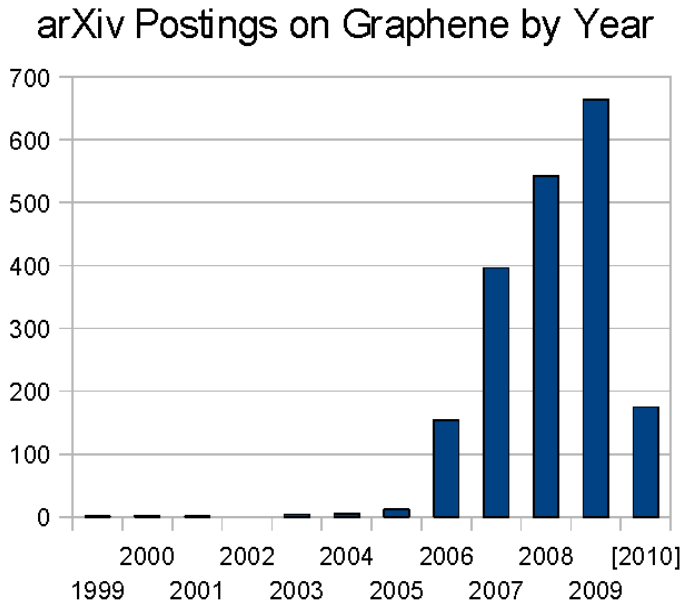
Photo: U. Montan

Andre Geim

Photo: U. Montan

Konstantin Novoselov

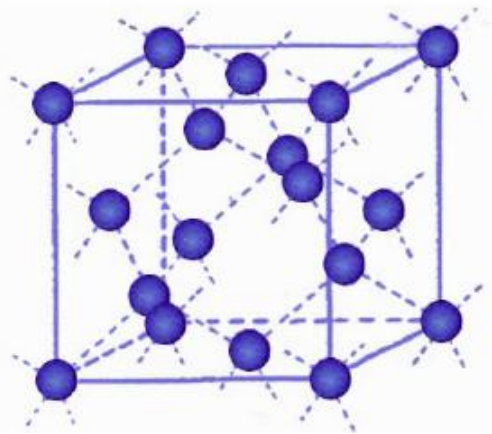
The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov *"for groundbreaking experiments regarding the two-dimensional material graphene"*



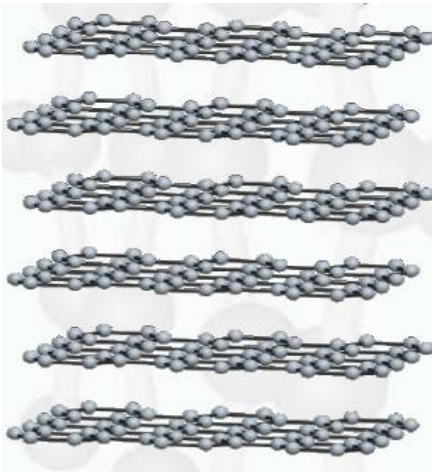
Buzzwords

- Honeycomb lattice
- massless Dirac Fermions
- Chirality / Helicity
- Pseudospin
- π-bonding / π*antibonding bands
- edge states
- zigzag / armchair edges
- Klein-Tunnelling
- Valey-degeneracy / Valey Isospin
- Trigonal warping
- Pseudo-superconductivity

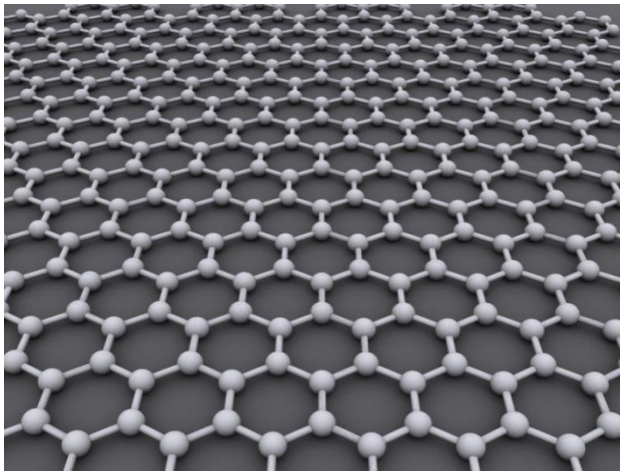
Diamant



Graphit

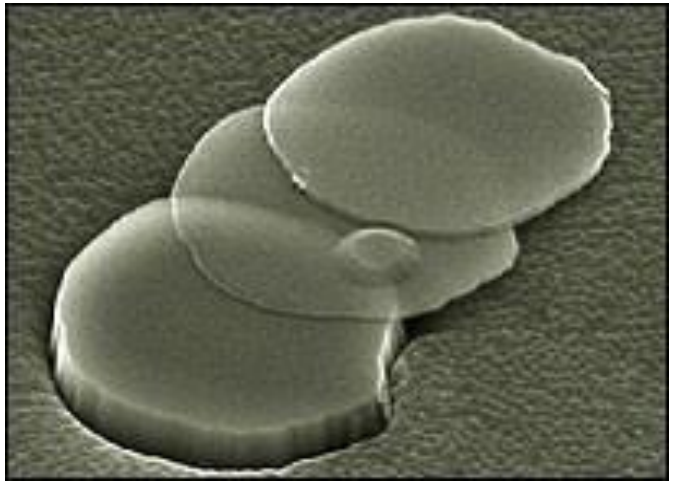


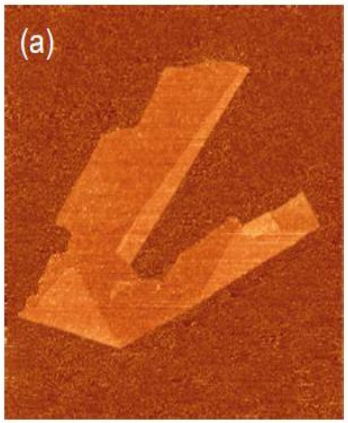
Graphen

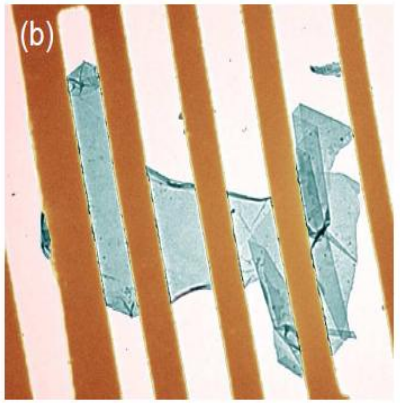


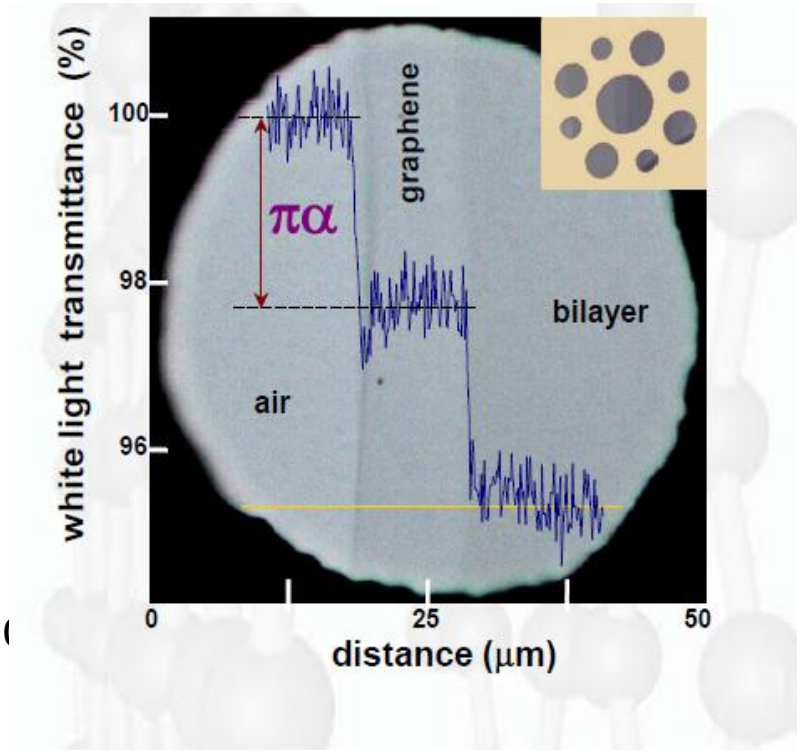
Elektronische Struktur von Graphen lange bekannt
Existenz lange für unmöglich gehalten (Mermin-Wagner Theorem)

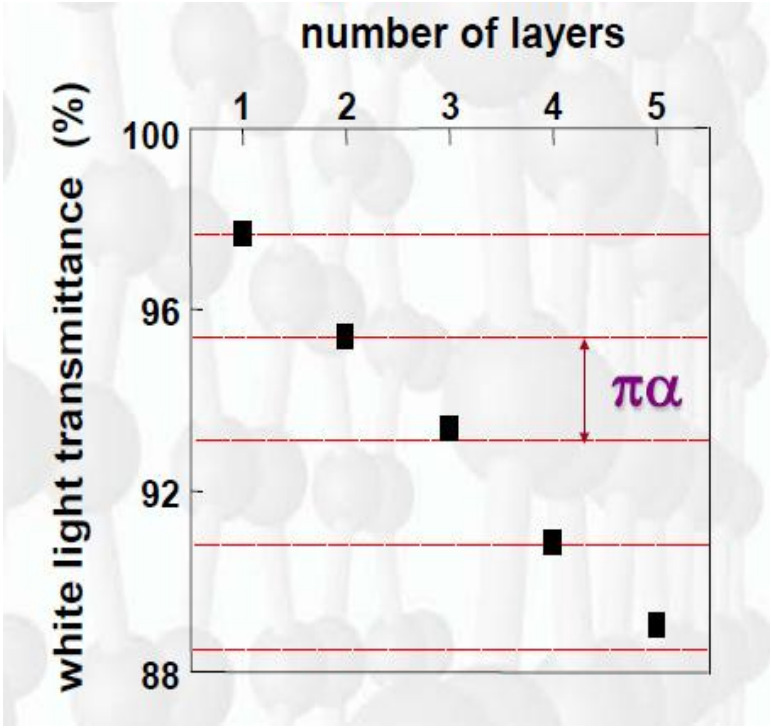
MWT: keine langreichweitige Ordnung bei T>0 in Systemen mit weniger als 3 Dimensionen
langreichweitige Ordnung der Atompositionen ➔ Kristall
langreichweitige Ordnung der magnetischen Momente ➔ Magnetismus



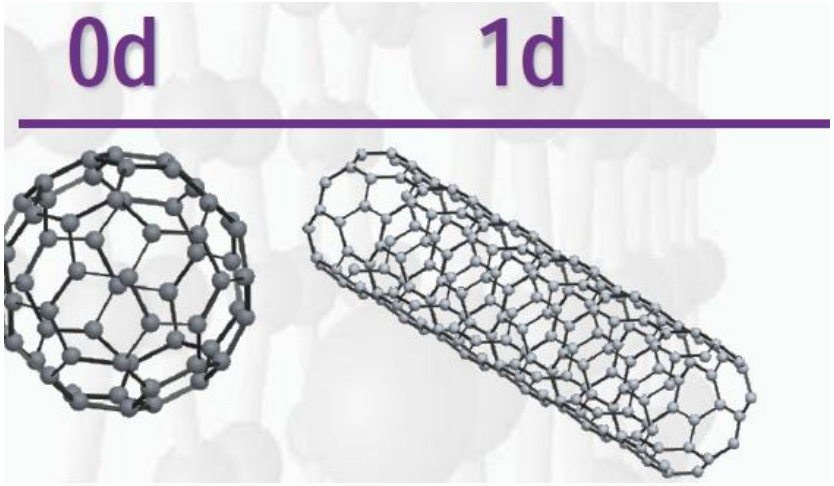

(a)

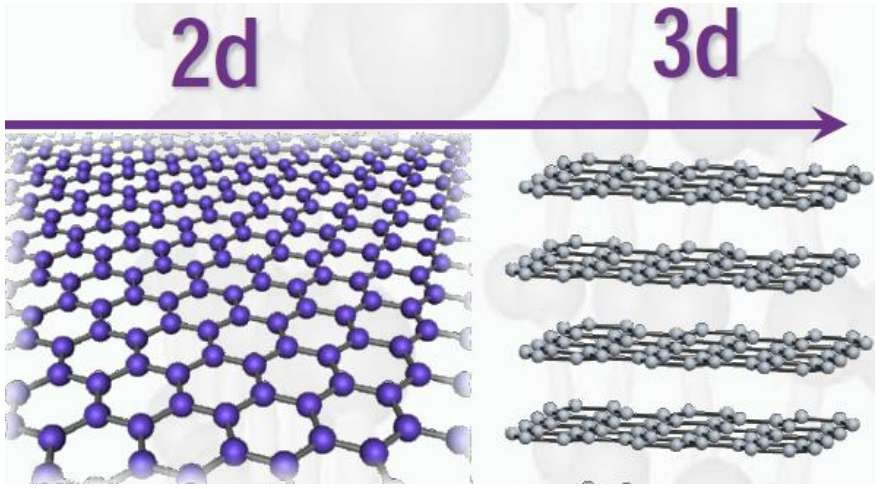

(b)

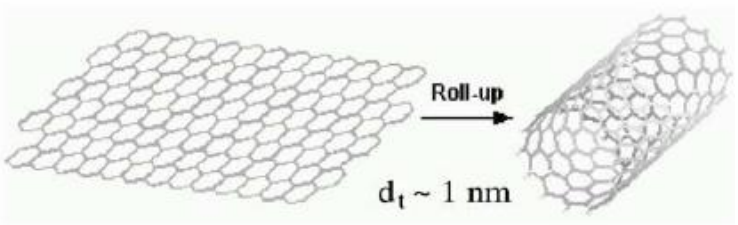

white light transmittance (%)
100
98
96
πα
graphene
bilayer
air
0
25
50
distance (μm)

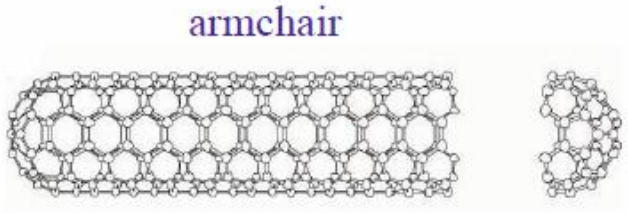

number of layers
1
2
3
4
5
white light transmittance (%)
100
96
92
88
πα

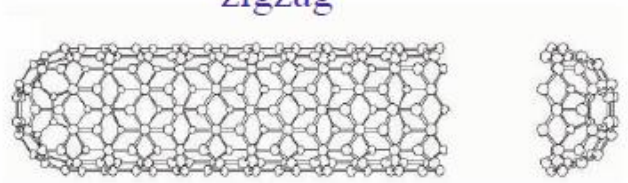
Allotropie von Kohlenstoff

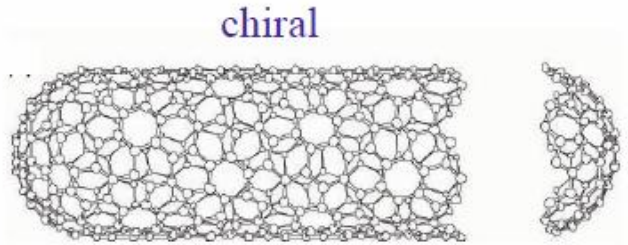










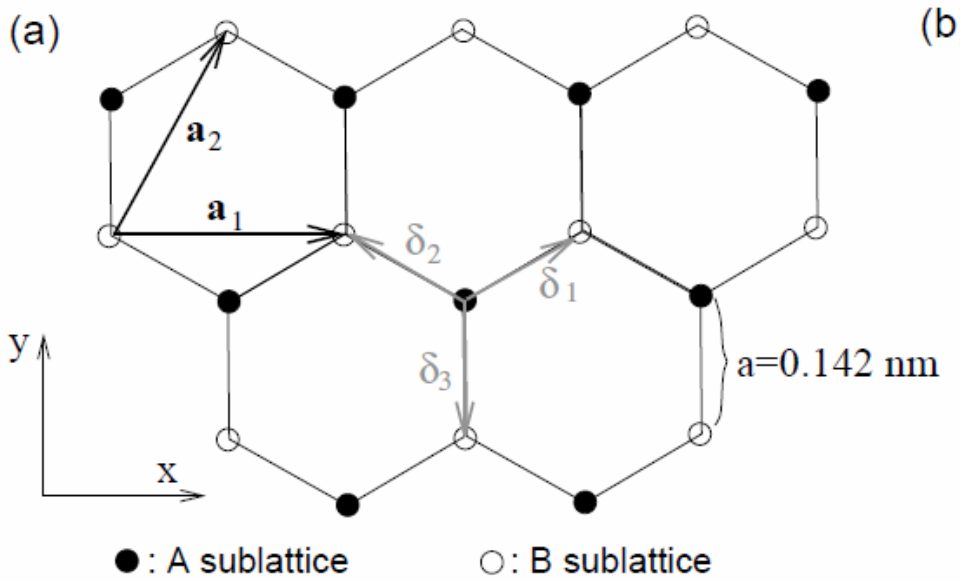


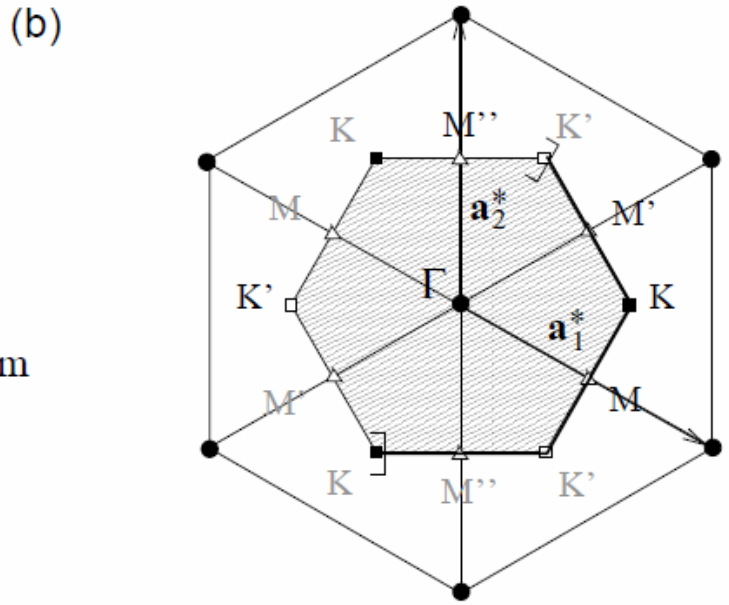
“Roadmap”:

- Struktur im Realraum (Gittervektorren, Einheitszelle, Basis,..)
- Struktur im k-Raum (Brillouin-Zone)
- “Chemie” (Elektronenkonfiguration, abgeschlossene “Schalen” von C)
- chemische Bindung (Hybridisierung, σ,π , bindend, anti-bindend)
- Bandstruktur: 1D-1 Band Tight Binding (“lineare Kette”, Wdh?)
- ➔Graphen E(k): 2D, 2Band TB, relativistische Dispersion

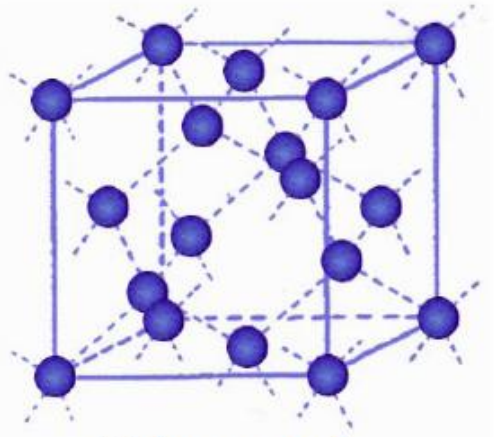
- Wie präpariert man Graphen?
- Wie kann man daraus einen Feldeffekttransistor bauen?
- Wie kann man einen npn-Transistor bauen?
- Klein Tunneln
- idealer Kristall ➔ Realität: Punktdefekte, Kantenzustände
- “molekulares Graphen”

Graphen – Struktur



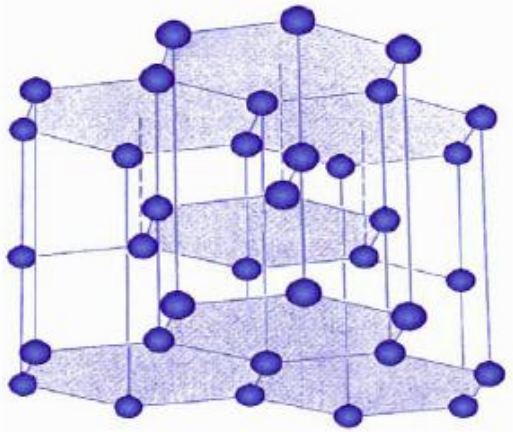


Zwei nicht-äquivalente K-Punkte



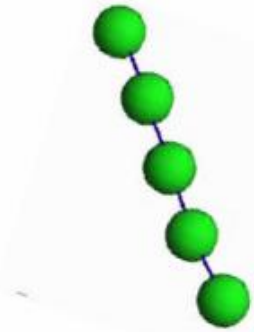
Diamond

sp^3 (3D) 1332 cm^{-1}



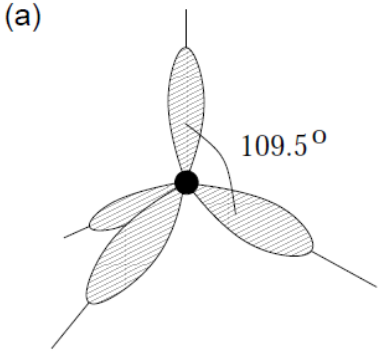
Graphite

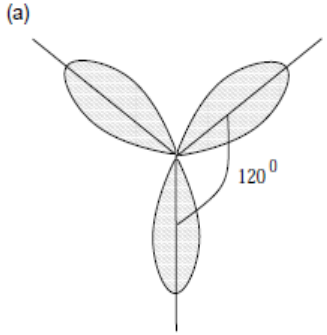
sp^2 (2D) 1582 cm^{-1}

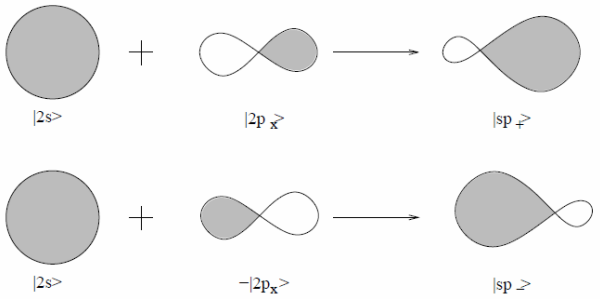


Chain

sp^1 (1D) 1855 cm^{-1}







$$
\begin{aligned}
|sp_1^2\rangle &= \frac{1}{\sqrt{3}}|2s\rangle - \sqrt{\frac{2}{3}}|2p_y\rangle, \\
|sp_2^2\rangle &= \frac{1}{\sqrt{3}}|2s\rangle + \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}}{2}|2p_x\rangle + \frac{1}{2}|2p_y\rangle\right), \\
|sp_3^2\rangle &= -\frac{1}{\sqrt{3}}|2s\rangle + \sqrt{\frac{2}{3}}\left(-\frac{\sqrt{3}}{2}|2p_x\rangle + \frac{1}{2}|2p_y\rangle\right).
\end{aligned}
$$

$$
|sp_+\rangle = \frac{1}{\sqrt{2}}\left(|2s\rangle + |2p_x\rangle\right),
$$

$$
|sp_-\rangle = \frac{1}{\sqrt{2}}\left(|2s\rangle - |2p_x\rangle\right).
$$