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Surface Transfer Doping of Diamond (100) by Organic Molecules

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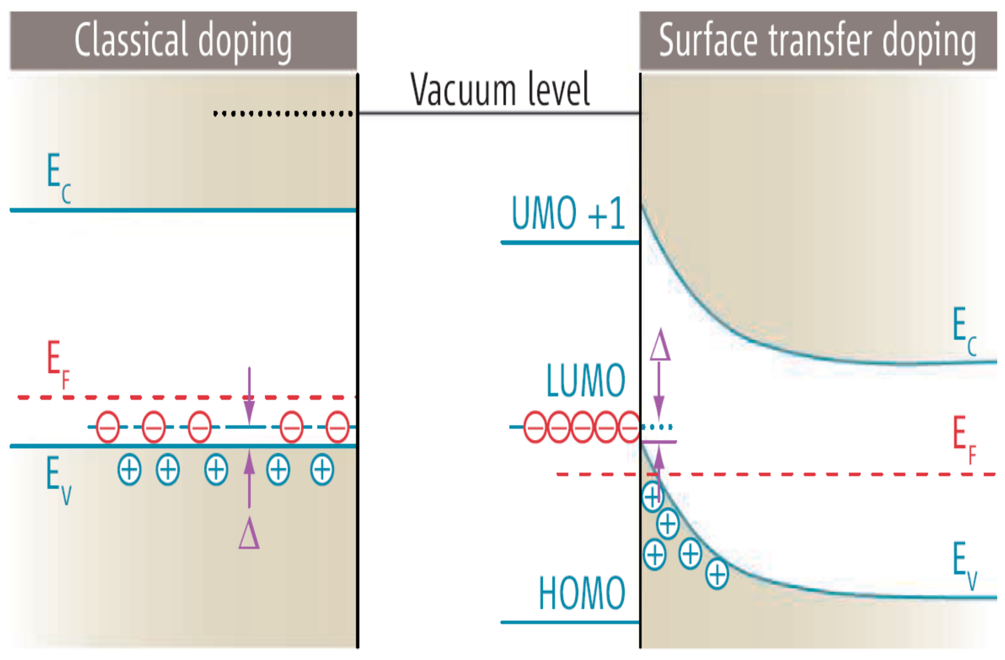
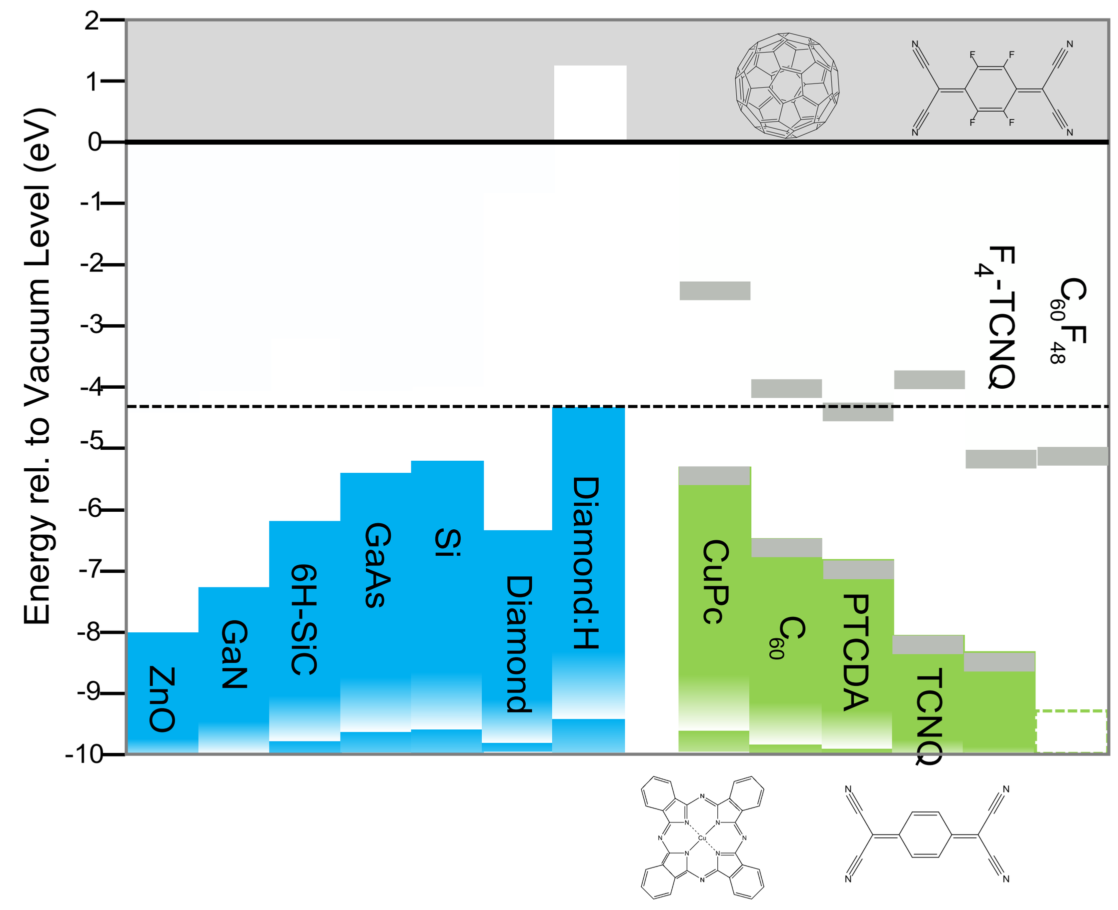
Introduction

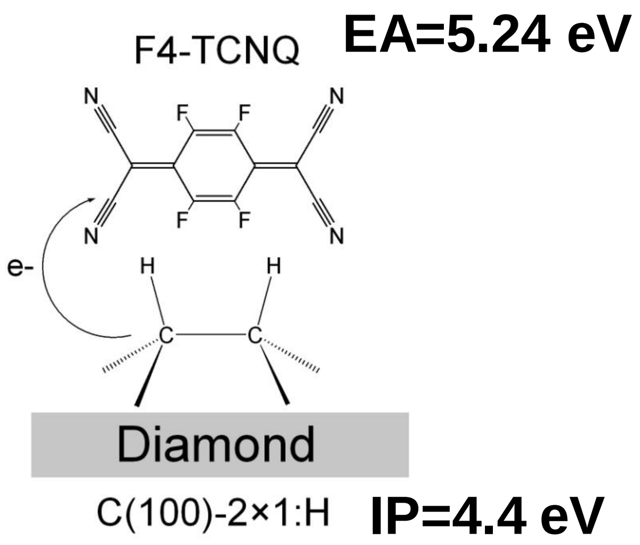
Despite of numerous exceptional electronic and mechanical properties of diamond, the development of diamond-based electronic devices is severely hampered by a number of setbacks of conventional doping of diamond such as high dopant activation energy and processing difficulties. Surface transfer doping, which is achieved by electron exchange between a semiconductor to its surface adsorbates, is highly promising to tackle this challenge.





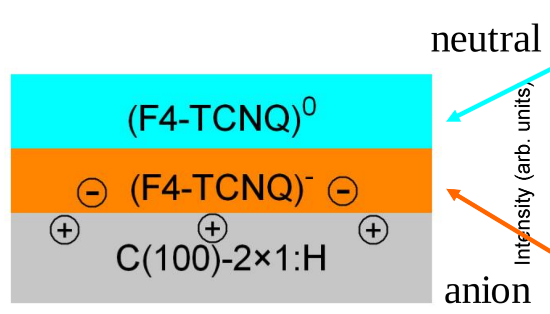
Results and Discussions

I: F_4-TCNQ

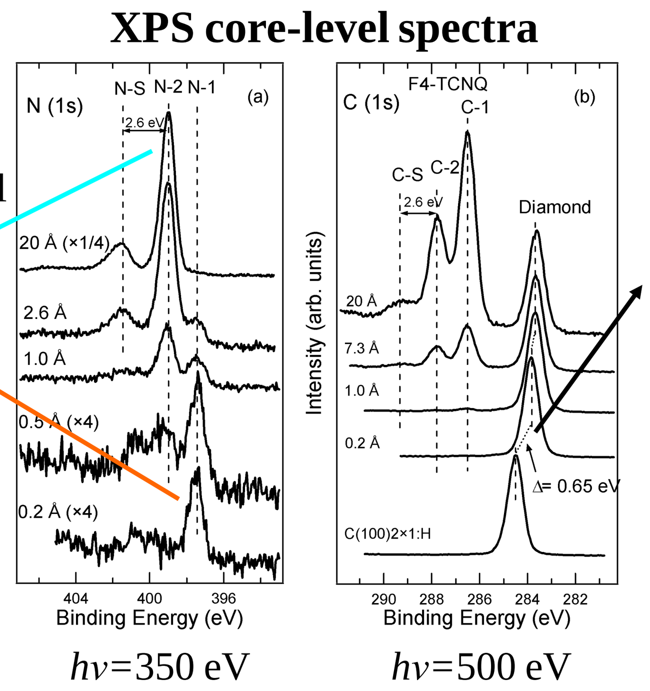


Favoring electron transfer from E_V of diamond to LUMO of F_4-TCNQ:

A excellent test bed for surface transfer doping

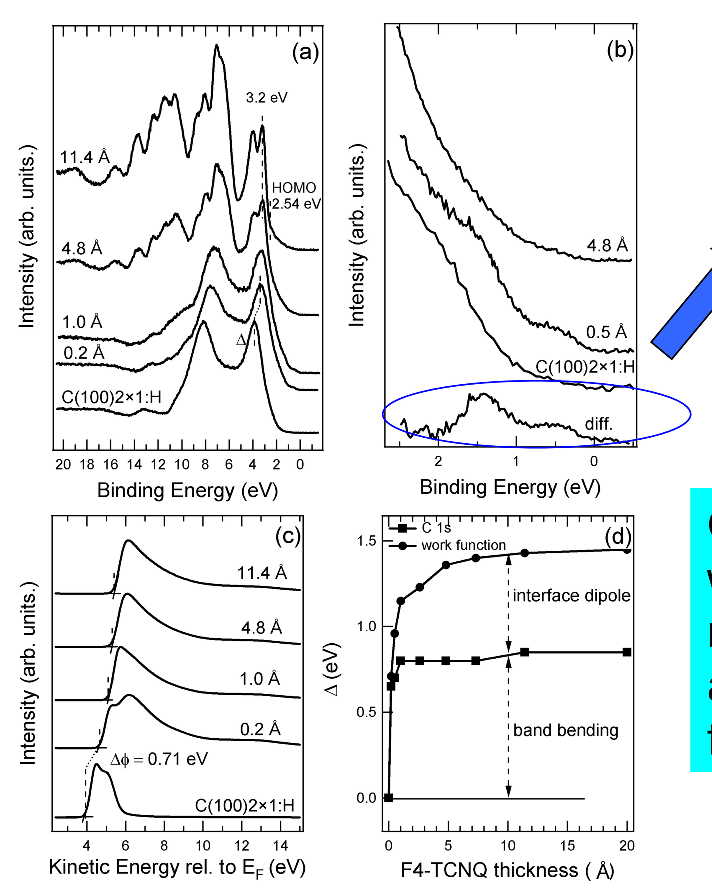


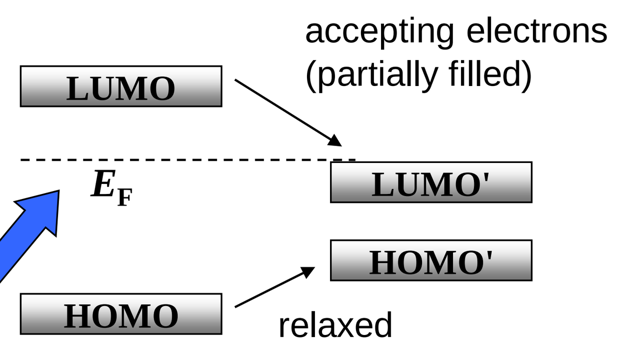
XPS core-level spectra



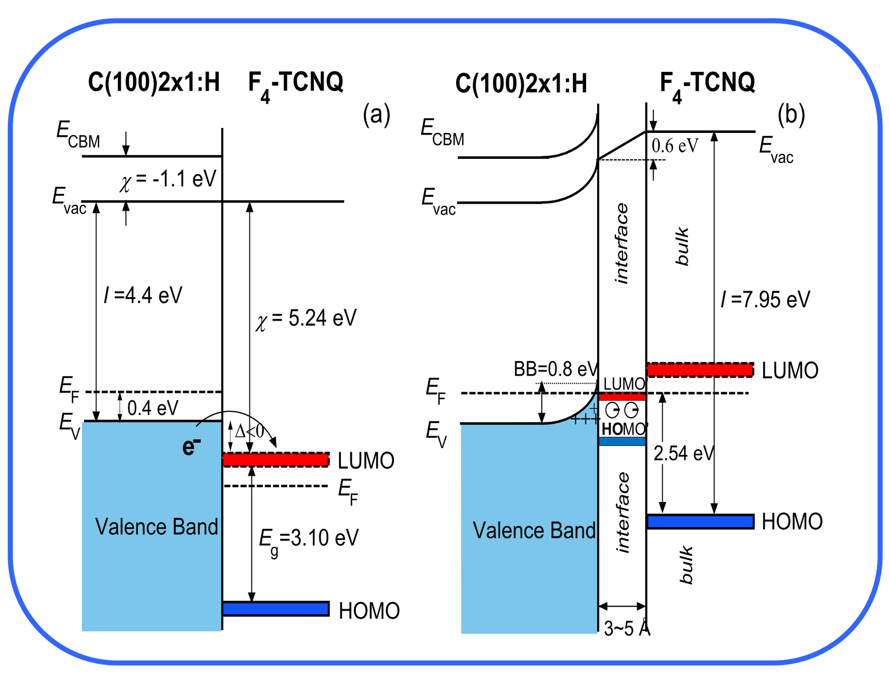
Upward band bending of up to 0.8 eV at diamond surface region, resulting from hole accumulation

Valence Band Spectra





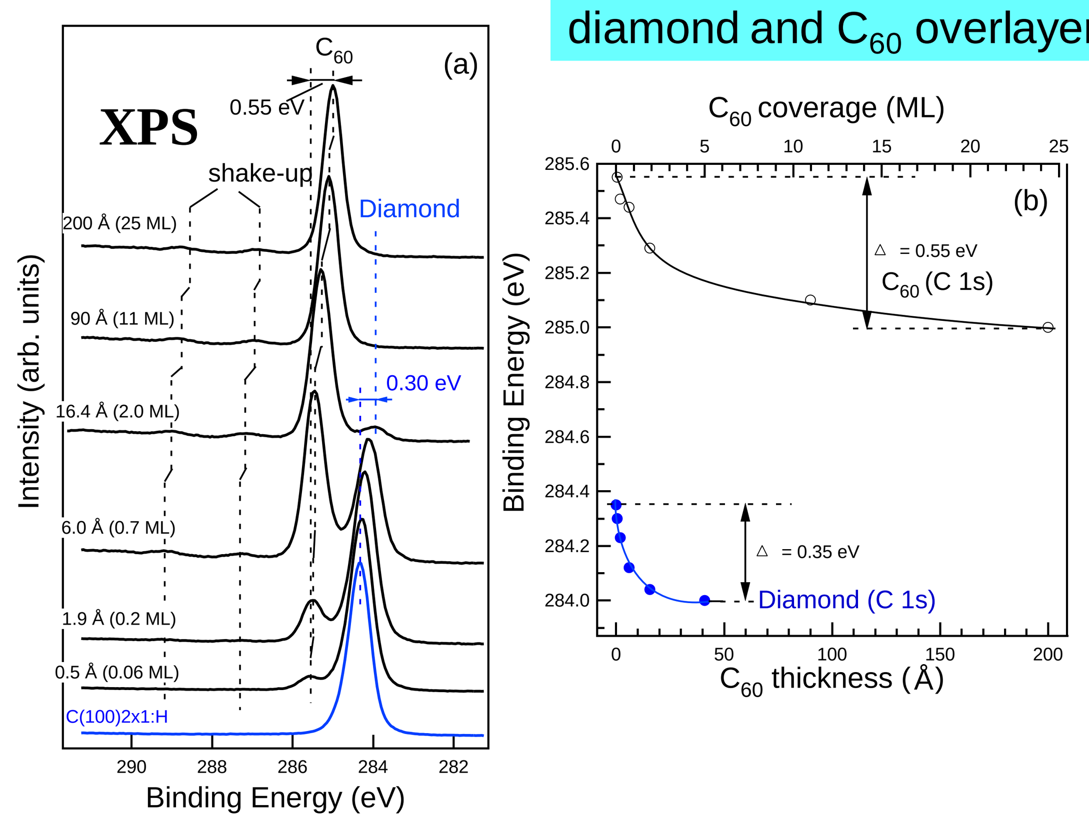
Change of work function with F_4-TCNQ deposition results from band bending and interface dipole formation

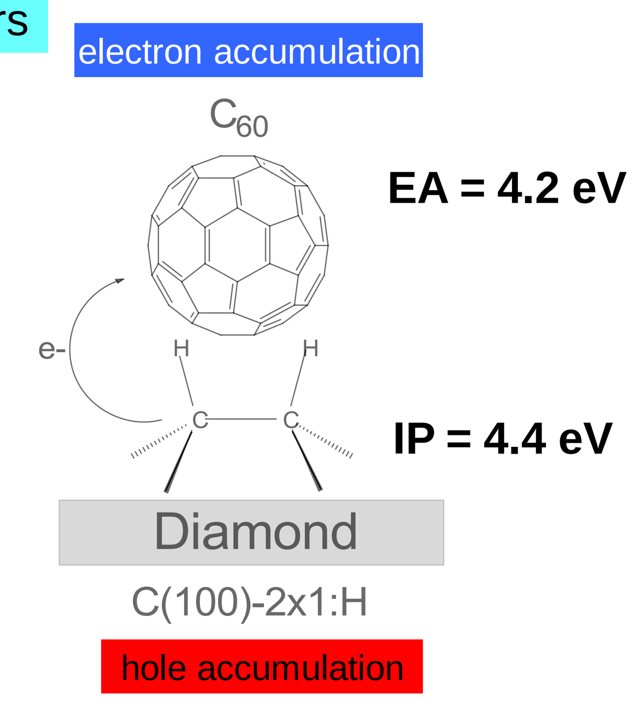


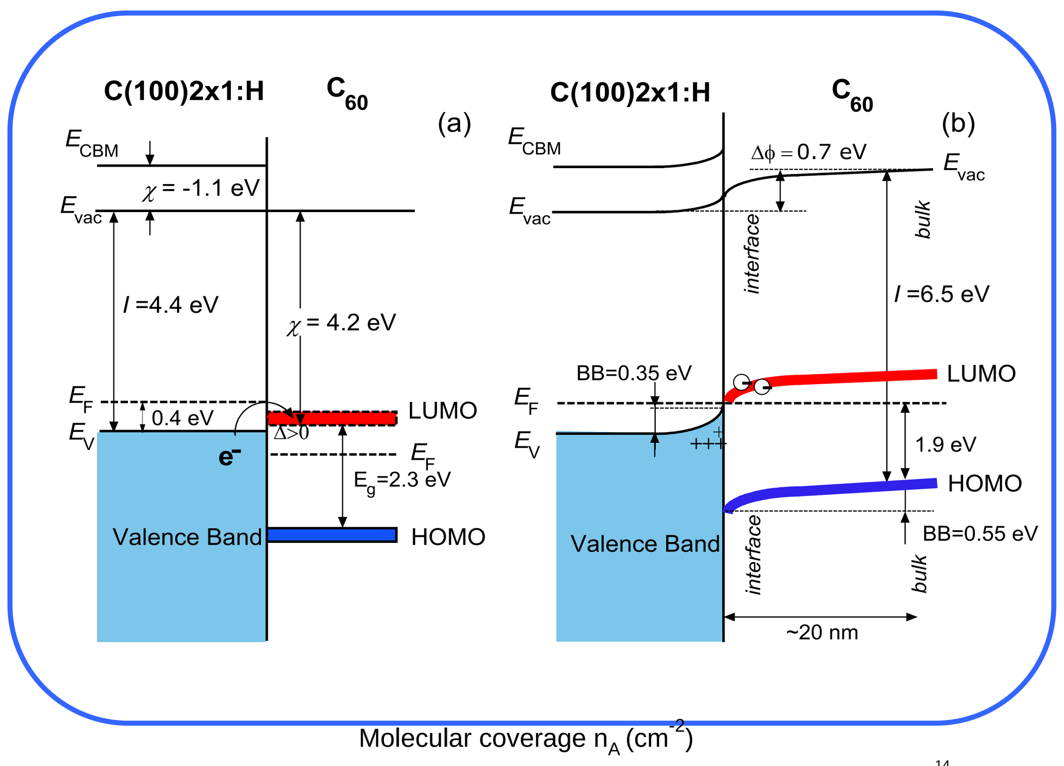
- ➢ F_4-TCNQ can already induce significant p-type surface transfer doping of diamond even in molecular form.
- ➢ Electrons are transferred from diamond valence band to molecular LUMOs.
- ➢ Diamond becomes degenerate at the surface.

II: C_{60}

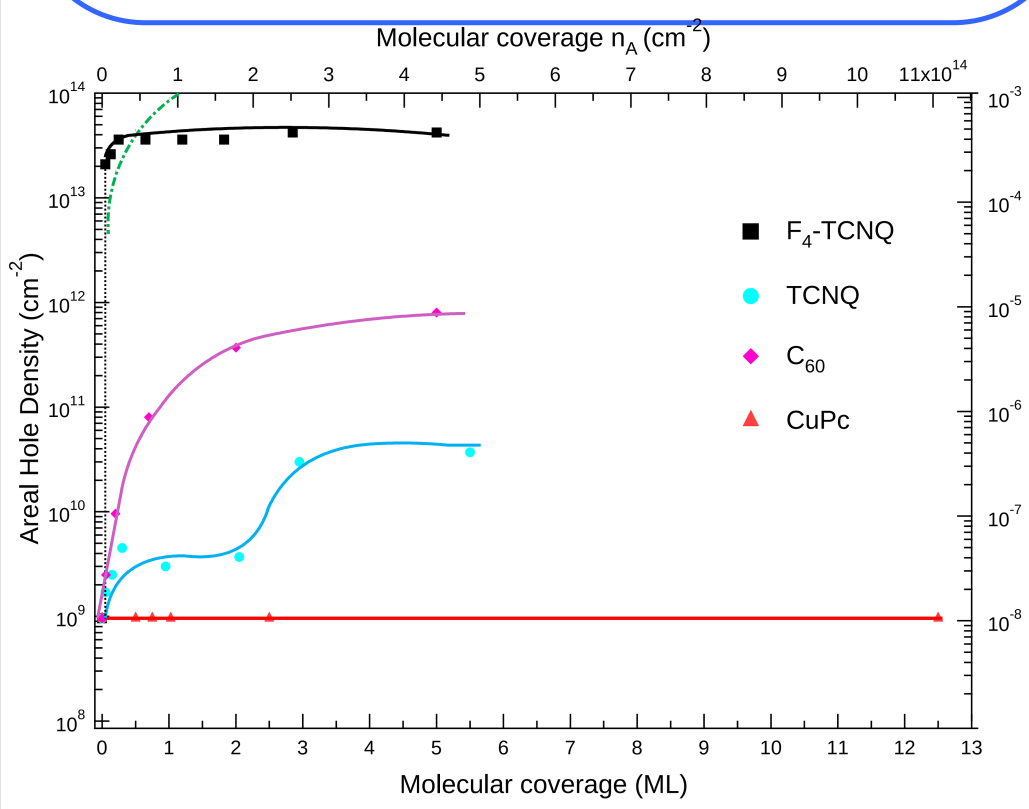
Band bendings in both diamond and C_{60} overlayers







- ➢ The formation of molecular solids is necessary for C_{60} to act as a surface acceptor.
- ➢ The interface resembles a extreme type II heterojunction with electrons transferred from diamond VB to LUMO derived bands of fullerene film



- ➢ F_4-TCNQ is the strongest surface acceptor with doping efficiency close to 1.
- ➢ C_{60} and TCNQ is only effective as surface acceptors when several monolayers of molecular solids are formed.
- ➢ CuPc cannot induce surface transfer doping at all.

Conclusions

- ◆ Controllable *p*-type surface transfer doping of diamond by organic molecules is unambiguously demonstrated through PES.
- ◆ The different doping efficiencies of tested molecules are related with their varied electron affinities.
- ◆ Surface transfer doping is a versatile scheme that can be applied to other semiconductor systems.