

Facile collisional dissociation of N₂ on a Si(111)-7x7 surface at room temperature

Ali Hamadeh,^a Elie Geagea,^a Judicaël Jeannoutot,^a Frank Palmino,^a Nicolas Breault,^b Alain Rochefort,^b Samar Hajjar-Garreau,^c Carmelo Pirri,^c Christophe M. Thomas^d and Frédéric Chérioux^{* a}

^a Université de Franche-Comté, CNRS, FEMTO-ST, 15B avenue des Montboucons, F-25030 Besançon cedex, France

^b Département de génie physique, Polytechnique Montréal, Canada H3C 3A7

^c IS2M, Université Haute-Alsace, CNRS, 3bis rue Alfred Werner, F-68093 Mulhouse cedex, France

^d Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris, F-75005 Paris, France

The industrial activation and transformation of N₂ to ammonia are carried out according to the well-known Haber–Bosch process, an old process invented about 100 years ago by F. Haber and C. Bosch. Hence, this reaction consumes about 2% of the world's energy supply and accounts for 1.44% of the CO₂ global emission.¹ Indeed, the limiting step of this reaction is the dissociation of N₂, from the triple N≡N bond thereof, which is the strongest bond in diatomic molecules.

In our work, we demonstrate that the strong N₂ bond can be efficiently dissociated at low pressure and ambient temperature on a Si(111)-7x7 surface. The reaction was experimentally investigated by scanning tunneling microscopy and X-ray photoemission spectroscopy. Experimental and density functional theory results suggest that relatively low thermal energy collision of N₂ with the surface can facilitate electron transfer from the Si(111)-7x7 surface to the π*-antibonding orbitals of N₂ that significantly weaken the N₂ bond. This facile N₂ triple bond dissociation on the surface leads to the formation of a Si₃N interface.

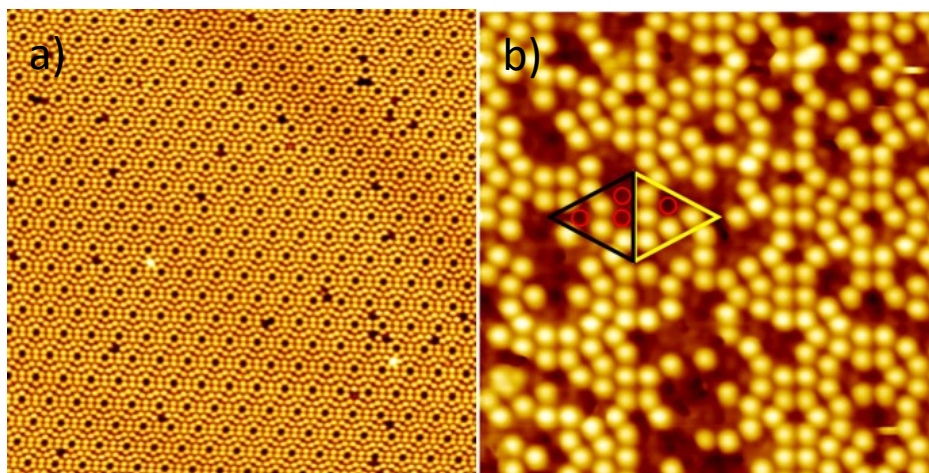


Figure 1: a) STM image (50x50 nm², $I_t = 200$ pA, $V_s = + 2$ V) of the Si(111)-7x7 surface. b) STM image (15x15 nm², $I_t = 200$ pA, $V_s = + 1.5$ V) recorded after exposition at $1 \cdot 10^{-5}$ mbar for 30 minutes. Darker spots are attributed to modified silicon adatoms, both adatoms of faulted (yellow triangle) or unfaultered (black triangle) half-unit cells are affected.

Our results could be relevant for fine comprehension of the preliminary steps of the growth of silicon nitride, which is extremely important for microelectronics. The investigation of the ability of Si(111)-7x7 for efficient synthesis of ammonia is currently being investigated.

Références

- [1] R. Schlogl, *R. Angew. Chem. Int. Ed.* **2003**, 42, 2004-2008.