I Milleuno Mestieri del Fisico:

La ricerca scientifica

La fisica dei vetri: *Il racconto del percorso di un giovane laureato in fisica, dalle giornate sui libri ad un vero lavoro in un moderno laboratorio di ricerca.*

Fabrizio Messina

Palermo, 17 Maggio 2007

Lavorare nell'ambito della ricerca?

Percorso:

1. Laurea

2. Dottorato di ricerca (3 anni) (*Retribuito!*)

3. Assegno di ricerca

4. Ricercatore

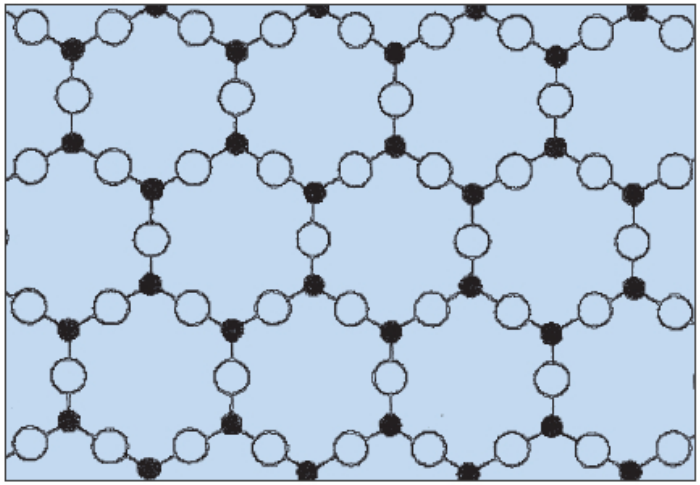
PRO:
Entusiasmante, attività creativa e molto autonoma, buona disponibilità di lavoro (anche all'estero).

CONTRO(?):
Richiede motivazione e impegno.

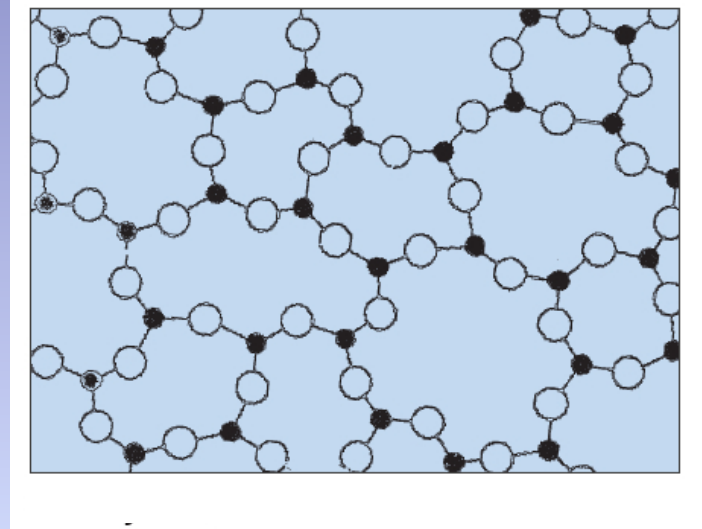
Un'esempio: la mia esperienza di dottorato (2004-2006).
Fisica dello stato solido: ricerca sugli effetti della radiazione laser UV su materiali "vetrosi".

Cos'è un vetro?

Solido cristallino



Solido amorfo (vetro)



Un vetro semplice: **la silice**, diossido di silicio (SiO_2)

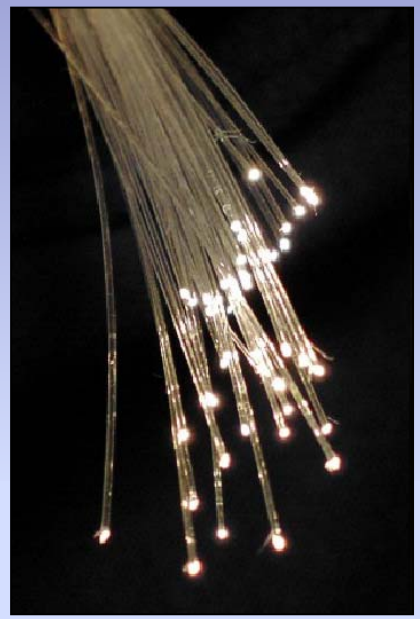
Problema: il disordine che caratterizza la struttura del vetro lo rende un sistema fisico molto più complesso rispetto al cristallo.

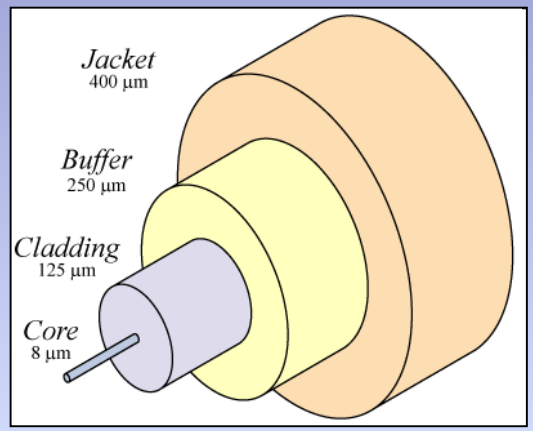
Fisica dei solidi amorfi: una delle grandi questioni aperte della fisica contemporanea

Perché studiare la silice: applicazioni

La ricerca in fisica è fortemente legata allo sviluppo di nuove tecnologie ed al miglioramento di quelle già esistenti.

Fibre ottiche





Alla base delle moderne tecnologie di telecomunicazione (Internet)

Altri componenti ottici (es. lenti)

In particolare in tutti i casi in cui è richiesta un'elevata trasparenza ultravioletta (UV)

Elettronica

(come isolante elettrico)

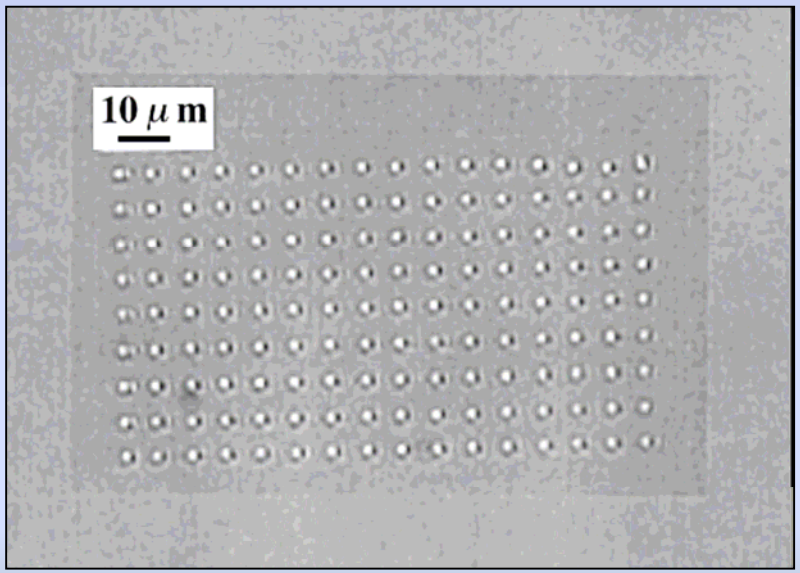
Effetti della radiazione laser e/o UV

Nelle applicazioni, la silice è spesso esposta a luce laser e/o UV.

1. La luce laser, in particolare UV, "danneggia" il materiale provocando una progressiva perdita di trasparenza.

Domande: Quali sono i processi microscopici alla base del "danno"?
Come è possibile produrre vetri "più resistenti"?

2. La luce UV può anche essere usata per produrre variazioni controllate delle proprietà del materiale, di interesse applicativo.

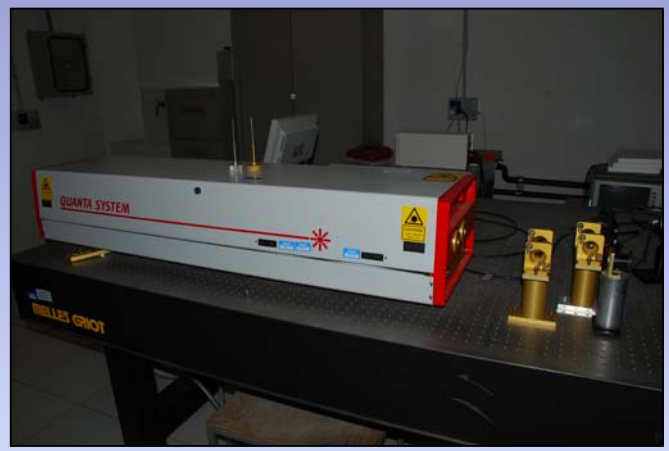


Esempio di memoria ottica 3D sperimentale (1998)
con spot di ~4μm distanti ~10μm.
(densità massime ottenute di circa 10^3 Gb/cm^3)

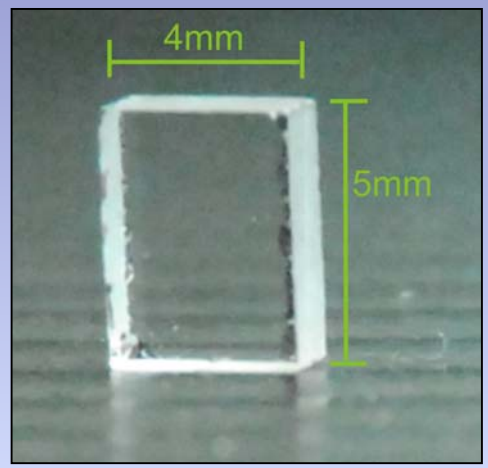
Alcuni dei miei risultati recenti

Esperimenti: **campioni di silice sono esposti ad irraggiamenti con laser UV**

Laser UV di alta potenza



Campione SiO_2

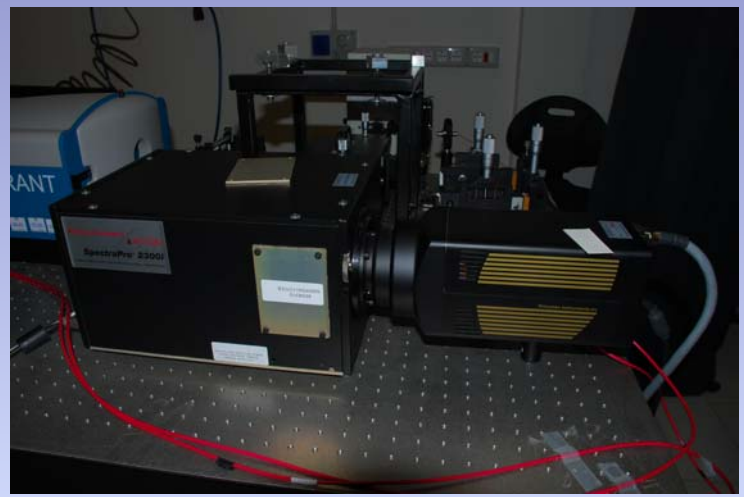


Durante un esperimento

Tecniche di indagine

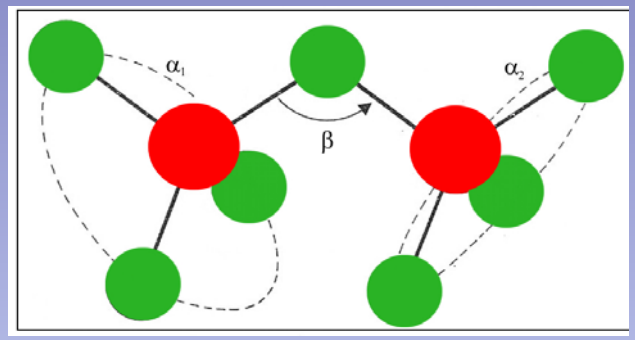
Spettroscopia di risonanza magnetica

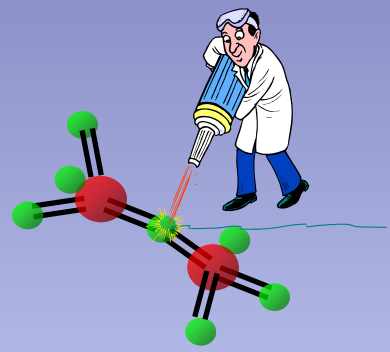
Spettroscopia di luminescenza



Spettroscopia infrarossa/Raman

Spettroscopia di assorbimento ottico

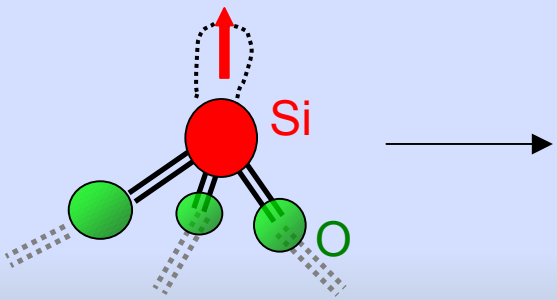


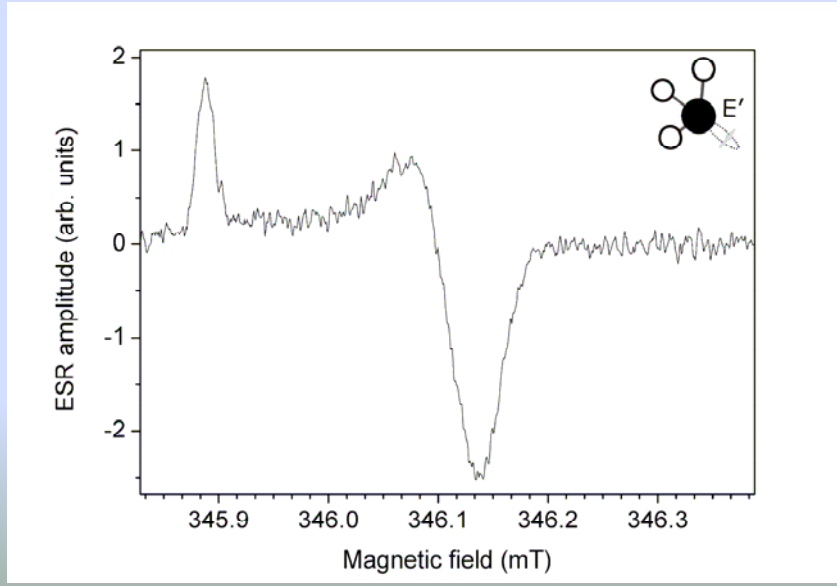


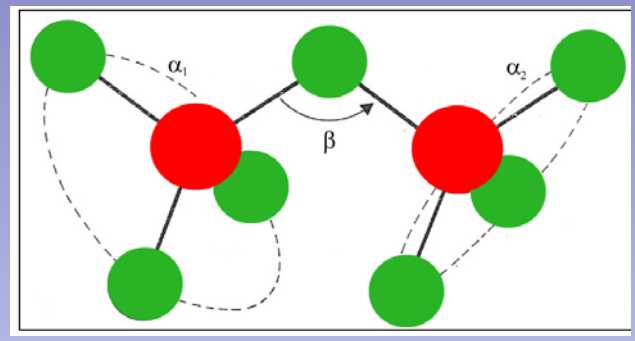
***Struttura** della silice non irradiata*: Atomi Si,O

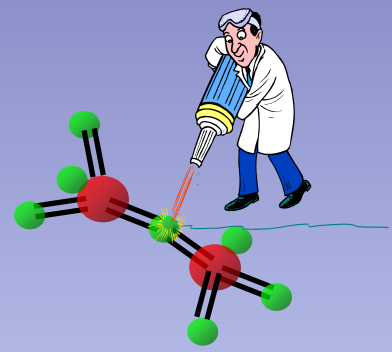
*Alterazioni microscopiche "**visibili**" attraverso diverse tecniche indirette*

Es. Risonanza magnetica





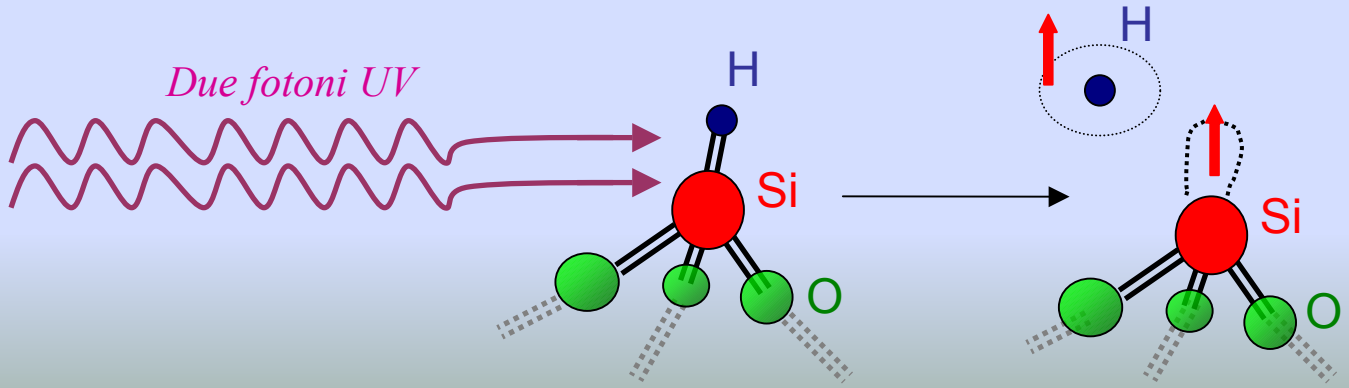




***Struttura** della silice non irradiata*: Atomi Si,O

Esperimenti, misure …

Modello: chiarito il meccanismo microscopico di danno (formazione di difetti)



Oltre il laboratorio…

Pubblicazione dei risultati su riviste internazionali..

IO

J. Phys. Chem. C 2007, 111, 6663−6667 6663

Character of the Reaction between Molecular Hydrogen and a Silicon Dangling Bond in Amorphous SiO_2

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The passivation by diffusing H_2 of silicon dangling bond defects (E′ centers, $O_3{\equiv}Si\bullet$) induced by laser irradiation in amorphous SiO_2 (silica) is investigated in situ at several temperatures. It is found that the reaction between the E′ center and H_2 requires an activation energy of 0.39 eV and that its kinetics is not diffusion-limited. The results are compared with previous findings on the other fundamental paramagnetic point defect in silica, the oxygen dangling bond, which features completely different reaction properties with H_2. Furthermore, a comparison is proposed with literature data on the reaction properties of surface E′ centers, of E′ centers embedded in silica films, and with theoretical calculations. In particular, the close agreement with the reaction properties of surface E′ centers with H_2 leads to the conclusion that the bulk and surface E′ varieties are indistinguishable from their reaction properties with molecular hydrogen.

Introduction

Amorphous silica (a-SiO_2) is a material of major scientific interest for its physical characteristics peculiar of the glassy state and for the many technological applications in optics and microelectronics. Generation of point defects, induced by laser or ionizing radiation, limits the applicative performance of the material, causing, in particular, the reduction of its native high optical transparency in the ultraviolet (UV).[1] The stability of point defects in a-SiO_2 is often conditioned by mobile species like hydrogen and oxygen, able to diffuse in the matrix in a wide temperature range.[1−5] The migration of mobile species in amorphous solids and their reactivity with point defects are both of fundamental and applicative interest.[4−7] In particular, diffusion of hydrogen in SiO_2 has been widely discussed due to the ubiquitous presence of this impurity in the material.[1−4] In this context, one of the basic processes is the reaction between H_2 and the silicon dangling bond ($O_3{\equiv}Si\bullet$) defect in silica (E′ center)[1,2,8−17]

$$E' + H_2 \rightarrow {\equiv}Si{-}H + H^0 \qquad (1)$$

The E′ center is a paramagnetic defect virtually found in every irradiated a-SiO_2 specimen, and its microscopic structure consists of an unpaired sp^3 electron localized on a 3-fold coordinated Si atom. This defect features a wide absorption band peaked at 5.8 eV, which usually dominates the UV optical absorption (OA) profile of the irradiated material.[1,17] In the presence of H_2

The reaction properties between H_2 and NBOHCs induced by laser irradiation have been clarified by recent experimental investigations,[4,5] which conclusively established that the reaction kinetics is diffusion-limited. This finding agrees with what is commonly expected for the reactions of mobile species with point defects in solids, systems where diffusion is usually so slow to be the actual bottleneck controlling the reaction rate. In these conditions, the characteristic activation energy of the reaction coincides with that of H_2 diffusion in silica, $\Delta E(H_2) \sim 0.4$ eV;[2,4] consistently, it was also shown that the kinetics of the reaction between NBOHC and H_2 is conditioned by the site-to-site statistical distribution of $\Delta E(H_2)$ in the glass,[2] known to be a fingerprint of the disordered structure of amorphous silica.[2,4]

In contrast, much less is known about the reaction properties of the E′ center. In fact, although the passivation of the E′ center by H_2 has been discussed by many experimental and theoretical works aiming to estimate the kinetic parameters of the process, it remains debated whether the reaction kinetics is diffusion- or reaction-limited.[9−16] Several theoretical studies have proposed the reaction to require an activation energy of a few tenths of an electronvolt.[10,12−14] Nevertheless, detailed experimental kinetic studies have been carried out only for surface E′ centers[11] and for E′ centers in thin silica films,[8] and even these two works report disagreeing results; the measured rates of reaction 1 at $T = 300$ K differ by 2 orders of magnitude, while the activation energies are 0.4 and 0.3 eV, respectively.[8,11] Most important,

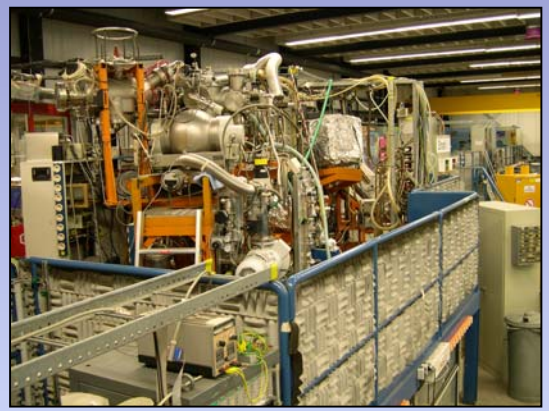
Oltre il laboratorio…

Presentazione dei propri risultati a congressi…

Oltre il laboratorio…

Sessioni di misura in laboratori internazionali

DESY, Amburgo (Germania), 2005.



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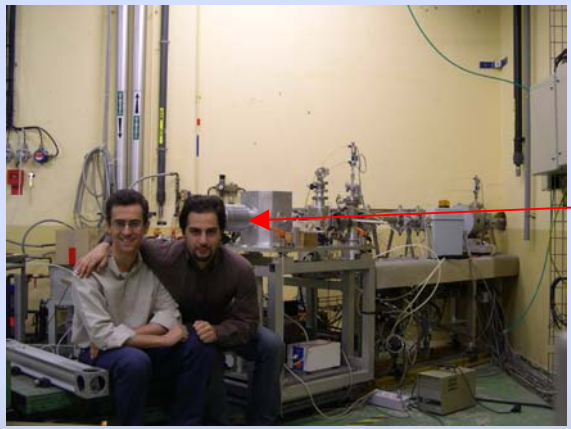
Palaiseau (Parigi, Francia), 2005.



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Oltre il laboratorio…

Sessioni di misura in laboratori internazionali

Durante il mio dottorato:

Londra (Regno Unito) (2004)
Bath (Regno Unito) (2004)
Chamonix (Francia) (2004)
Amburgo (Germania) (2004)
Amburgo (Germania) (2005)
Palaiseau (Francia) (2005)
Milano (Italia) (2006)

Fine