# Transient Effects During Sputtering of a-C:H Surfaces by Nitrogen Ions

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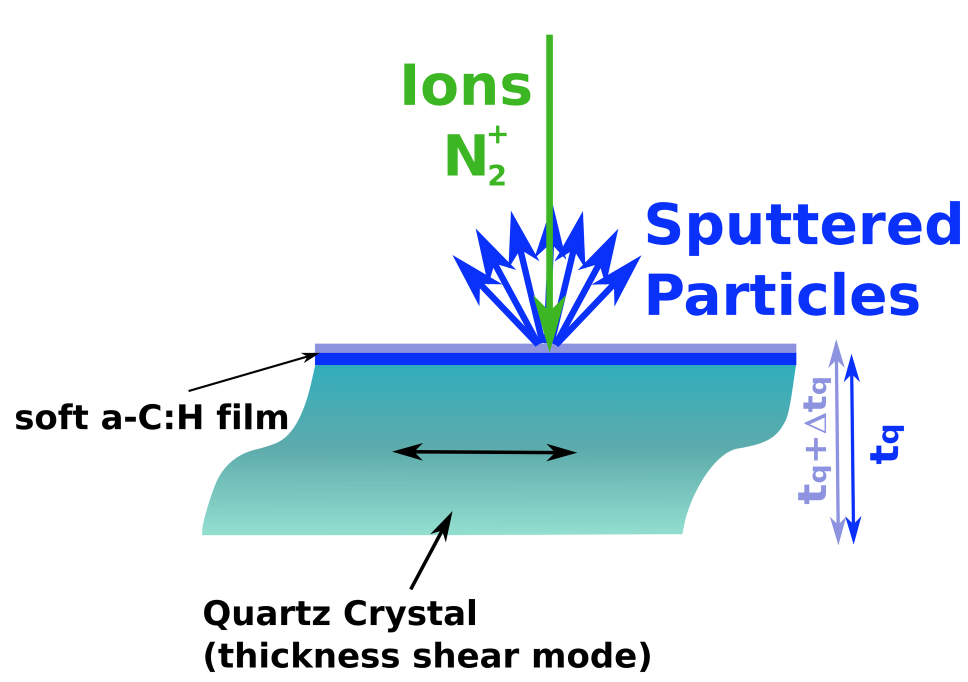
## Abstract

Nitrogen seeding is presently used in fusion devices to reduce the local power load on highly exposed surfaces by enhanced radiative cooling [1]. This is why the interaction of nitrogen ions with amorphous hydrogenated carbon (a-C:H) thin films, which are the result of co-deposition of carbon and hydrogen isotopes in carbon containing fusion devices, is of considerable interest [2, 3]. During the interaction of energetic ions with hydrocarbon surfaces a modified surface layer builds up with different properties compared to the bulk film [4]. On the one hand bond breaking within the ion penetration depth modifies the carbon network and leads to a hydrogen-depleted layer. On the other hand impinging nitrogen ions are implanted. In steady state the resulting top layer is dynamically reformed and its underlying bulk becomes thinner. Up to now key parameters like the sputtering yield could only be detected for that steady state erosion but were not accessible for the transient phase. Here first experimental measurements of the sputtering yield during this transient phase are presented.

## Experiment

### The QCM Principle – In Situ Sputtering Yield Determination




*Schematic drawing illustrating the basic concept of a quartz crystal microbalance. Total mass changes of the target film are detected in situ via changes in the resonance frequency of a quartz crystal driven at its thickness shear mode.*

- soft a-C:H layer (H content 50 %) evaporated as thin film on quartz electrode
- total sputtering yield *Y* of target film determined from frequency change *df/dt*:

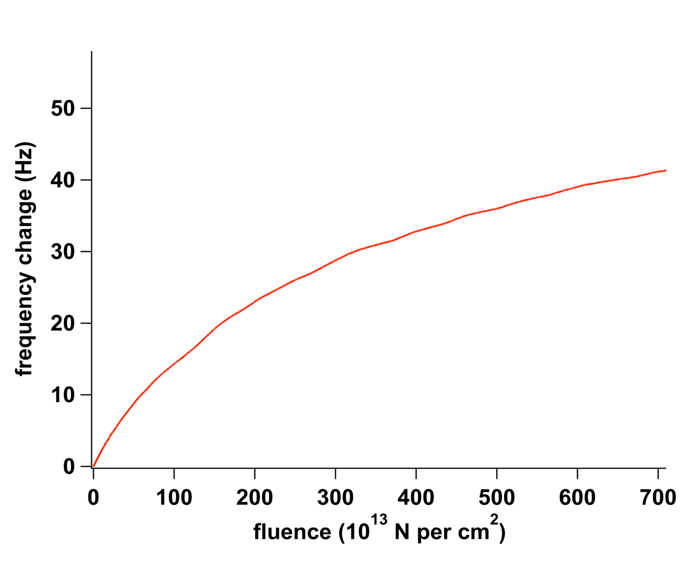
$$Y = \frac{C}{j} \cdot \frac{df}{dt}$$

C ... constant
j ... current density

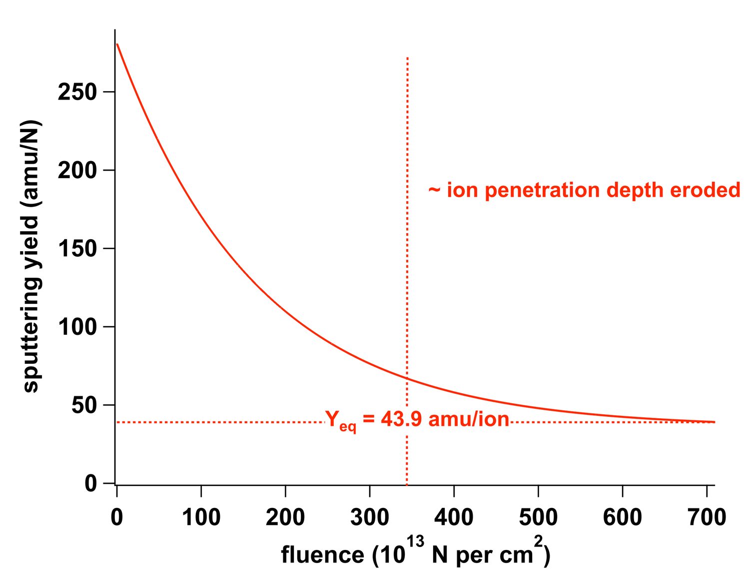
- Accuracy: $10^{-5}$ µg/s or ~$10^{-2}$ a-C:H monolayers [5]
- a-C:H target is homogenously irradiated with a $N_2^+$ ion beam produced either in an ECR ion source at the IAP in Vienna or at the particle beam experiment MAJESTIX in Garching.

### 1000 eV $N_2^+$ on a-C:H (soft)

**observed frequency change**

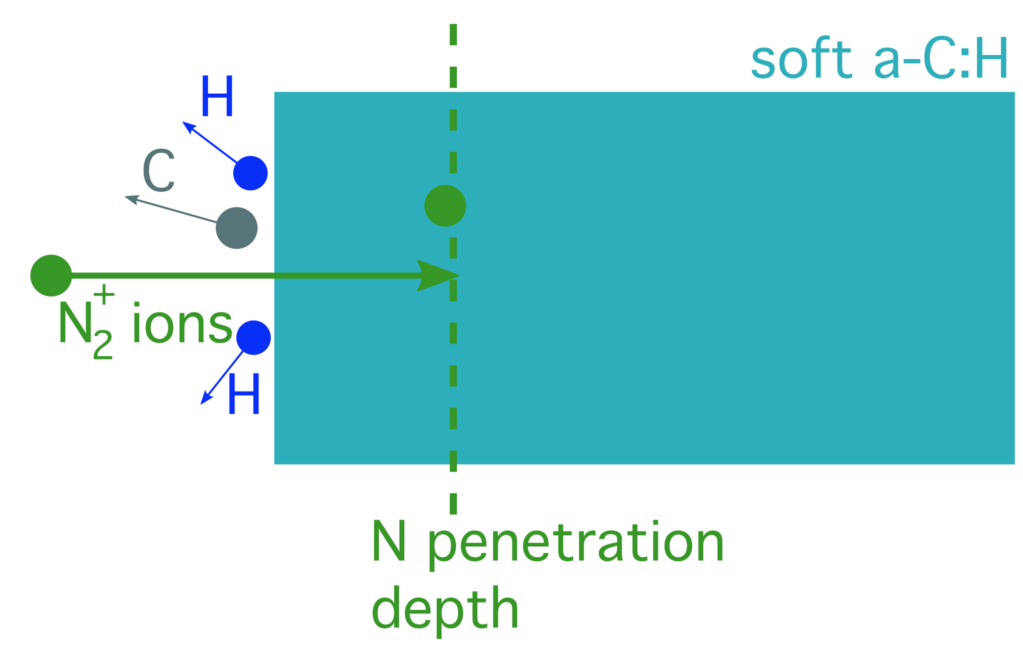



**determined evolution of the sputtering yield**



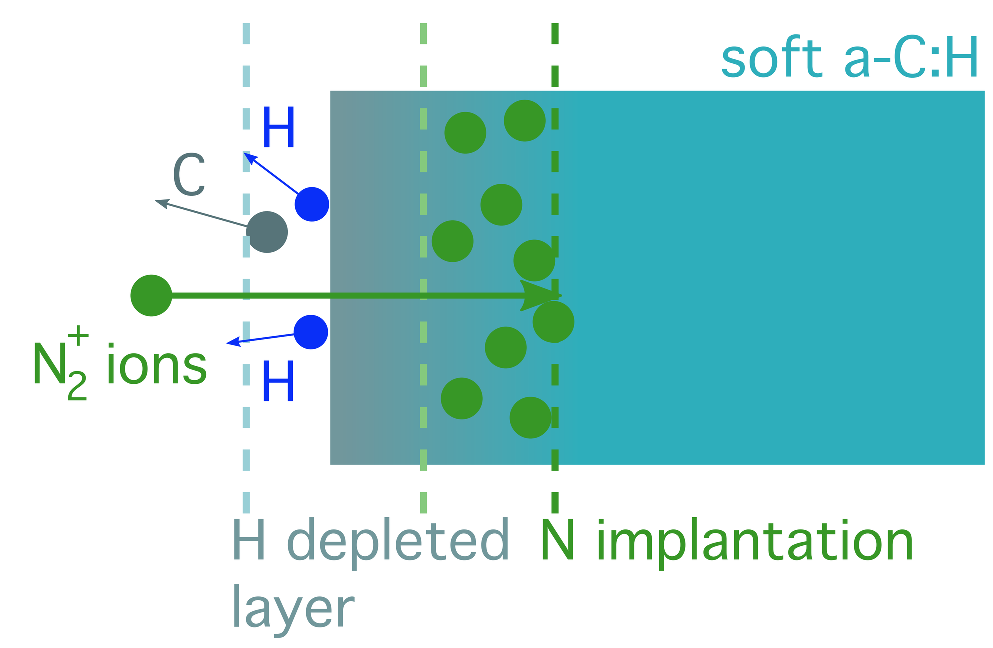

*The frequency change of the quartz crystal under $N_2^+$ bombardement is monitored as a function of the ion fluence (left). From this, the evolution of the sputtering yield of the a-C:H layer is evaluated (right). At first an elevated sputtering yield is observed which then decreases exponentially with fluence. After a fluence of some $10^{15}$ N per cm$^2$ the sputtering yield saturates and steady state conditions are reached. This behaviour can be explained by the formation of a H depleted, N containing top layer which in steady state eventually is dynamically reformed while its underlying bulk becomes thinner.*

## Transient Sputtering Process



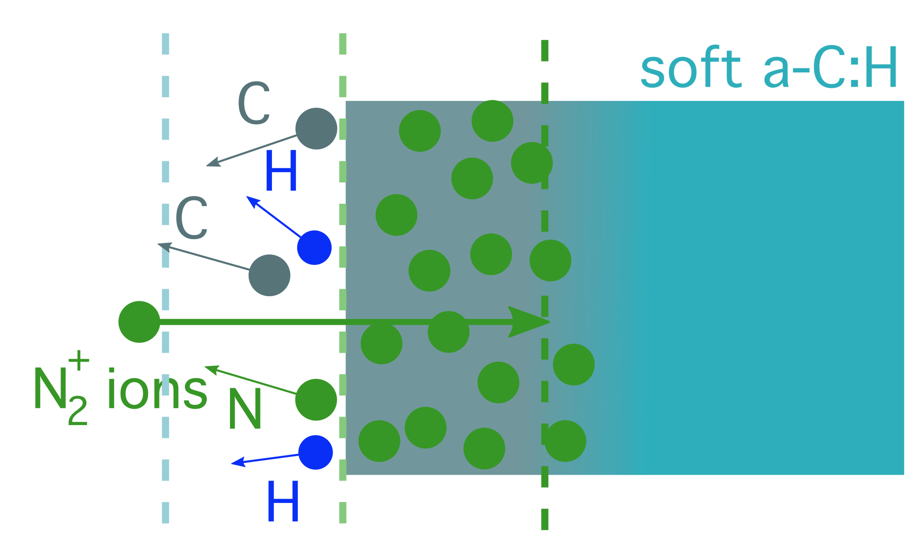

**virgin a-C:H**

- preferential H erosion (bond breaking within the ion penetration depth [4])
- C sputtering
- N implantation within the ion penetration depth




**transient phase**

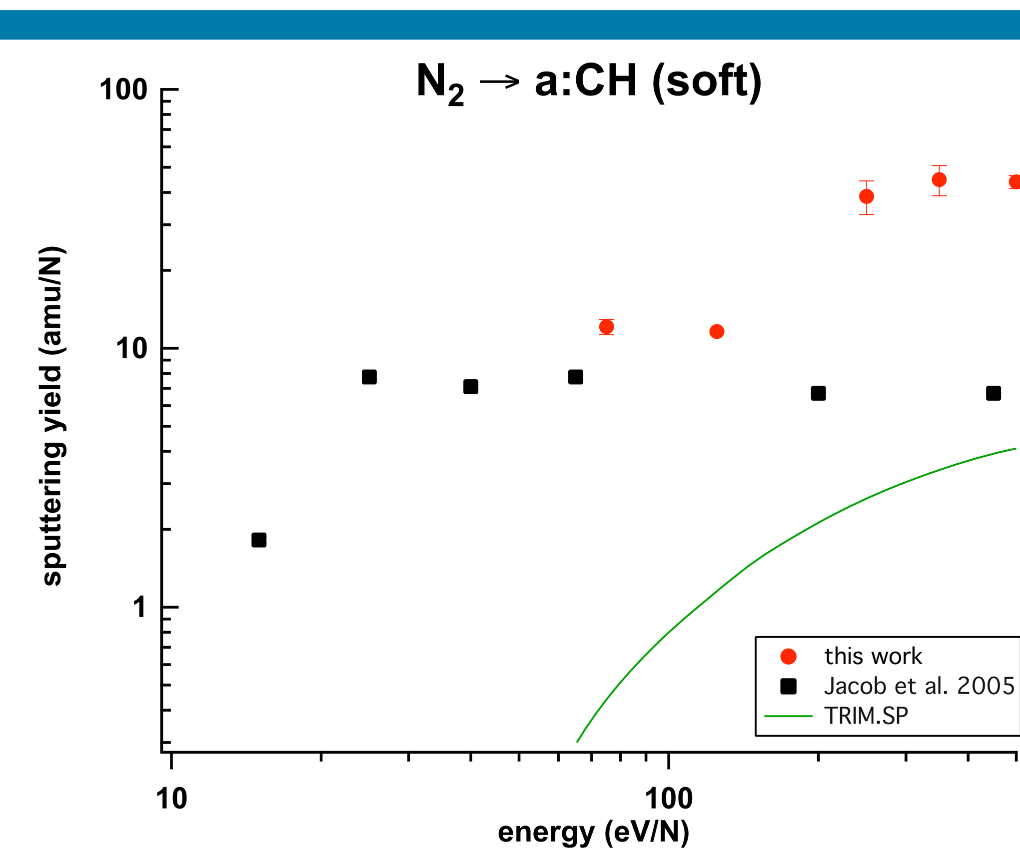
- built-up of a H depleted, N containing top layer
- exponential decrease of total sputtering yield according to decreasing H content in the top layer




**steady state**

- erosion of C, H and N
- dynamic equilibrium for formation of a H depleted, N containing top layer with erosion

## Steady State




*Comparison of the obtained steady-state sputtering yields for the impact of $N_2^+$ ions on soft a-C:H with previous data [2] for hard a-C:H and the results of TRIM.SP calculations (physical sputtering only) for a carbon surface [6]. Both sputtering yields as well as energies are normalized to the number of incident N atoms.*

*The obtained sputtering yields lie considerably above the TRIM.SP results, because kinetic sputtering effects alone, as considerd by TRIM.SP, do not suffice to describe the sputtering of a-C:H by N [2].*

## References

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