Plasmas are convenient sources of radiation and energy for driving chemical and physical processes. The interaction between plasma constituents and molecules in a multitude of pathways for e.g. ionization and/or the initiation of chemical reactions.

The reactivity of excited hydrogen towards tin and in general elements of Group 14 has been described in the literature for decades. Likewise, the thermodynamic instability of the resulting metal hydrides and the catalytic effect of metal surfaces regarding their decomposition is known since long. This chemistry has recently gained importance for the modeling of high energy H₂ plasmas in the presence of tin, which requires knowledge of the neutral and ionic reaction channels and mechanisms.

The initial interaction in the formation of metal hydrides is a heterogeneous gas/surface reaction of excited atomic H and metal atoms M, in which successive H-MH bonds are formed. The volatile metal hydrides thus formed subsequently desorb and may subsequently adsorb on other metal surfaces and decompose.

A custom low-pressure RF discharge generates the reagent ions H⁺ within a hydrogen plasma fed by a adjustable continuous gas flow [1]. The plasma source consists of an electrode-less, helical coil resonator (HCR) providing the RF energy to sustain the discharge, which is classified as a high density plasma [2]. Typical operation pressures range between 0.1 and 10 mbar.

The continuously generated ions are brought into contact with the solid metal samples [3] by the gas flow within the glass tube (2). The tube itself is additionally pumped by the first differentially pumped stage (0.1 – 10 mbar) of the used flight mass spectrometer (TOF-MS) [4].

**Methods**

**Mass spectrometer:** C-TOF time of flight mass spectrometer equipped with custom ion trap stage (TOFRAG AG, Thur, Switzerland)

**RF power supplies:** Modified VUV lamp RF power supplies (Heraeus GmbH, Hanau, Germany)

**Gases:** Hydrogen 5.0 and Argon 5.0 (Weiser Group GmbH, Krefeld, Germany)

**Software:** Gaussian 16. [5] and GaussView 6.0.16

**UV-Vis spectrometer:** HR 320 (Hitachi, Tokyo, Japan)

**Basic chemical assumption**

The RF discharge primarily generates electronically excited H species and H⁺ ions. The latter react with molecular hydrogen to form H₂. In the presence of H₂ or synthetic air, H₂ and also H⁺ are readily formed. In contrast to H₂, the adsorption of reactive H species leads to a subsequent formation of tin hydrides (SnHₓ), which either desorbs on the surface or desorbs into the gas phase [3,5].

Tin oxide is reduced by atomic hydrogen to tin metal and water. In the gas phase, a reaction cascade leads to a multitude of tin hydrides, which is shown in Fig. 2.

In this scheme (Eley-Rideal mechanism), more H is consumed than expected by a simple recombination of adsorbed and newly arriving H atoms. Tin oxide tends to spontaneously decay into the elements, a process which is accelerated by reactive surfaces [10,13] (order kinetics [2]).

Fig. 3 schematically shows the reaction channels of these tin compounds [3].

**Experimental setup**

**Surface interaction of selected transition metals and semiconductors with H2 plasma generated species**

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**Conclusion & Outlook**

**Conclusions:**

- It has been confirmed that plasma generated excited hydrogen species are capable of generating gas phase metal compounds via hydride formation.
- The experimental data agree with the expected isotopic patterns of stannane and its dimer, as well as tin oxide.
- Ab initio calculations show the relative decreasing stability of the tin hydride species as compared to the diatomic SnH and SnH₂, so they appear to be extremely unstable, which is most probably the reason why the are not detected in the recorded mass spectra.
- Experiments with nickel, tantalum, and silicon reveal no signals of the corresponding ions, most probably due to a strong protective oxide layer, very low stability of the ion hydrides, or insufficient sensitivity of the employed set-up.

**Outlook:**

- Optimization of the ion transfer from formation to analysis.
- Measurement of neutral metal hydrides species.
- Images of metal surfaces with SEM before and after treatment with H-plasmas and their generated species.
- Further ab-initio calculations regarding the stability of metal hydrides and simulations of the formation of hydrides on metal surfaces with MD simulations.

**Literature**


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