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Hot filament-dissociation of $(CH_3)_3SiH$ and $(CH_3)_4Si$, probed by vacuum ultra violet laser time of flight mass spectroscopy

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Abstract

The decomposition of trimethylsilane and tetramethylsilane has been investigated for the first time, using hot wire (catalytic) at various temperatures. Trimethylsilane is catalytic-dissociated in these species SiH_2, CH_3SiH, CH_3, CH_2Si. Time of flight mass spectroscopy signal of these species are linearly increasing with increasing catalytic-temperature. Time of flight mass spectroscopy (TOFMS) signals of $(CH_3)_3SiH$ and photodissociated into $(CH_3)_2SiH$ are decreasing with increasing hot filament temperature. TOFMS signal of $(CH_3)_4Si$ is decreasing with increasing hot wire temperature, but $(CH_3)_3Si$ signal is almost constant with increasing the temperature. We calculated activation energies of dissociated species of the parental molecules for fundamental information of reaction kinetics for the first time. Catalytic-dissociation of trimethylsilane, and tetramethylsilane single source time of flight coupled single photon VUV (118 nm) photoionization collisionless radicals at temperature range of tungsten filament 800–2360 K. The study is focused to understand the fundamental information on reaction kinetics of these molecules at hot wire temperature, and processes of catalytic-chemical vapour deposition (Cat-CVD) technique which could be implemented in amorphous and crystalline SiC semiconductors thin films.
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Keywords: VUV time of flight mass spectroscopy; Catalytic-dissociation; Photofragmentation and photoionization; Activation energies; Molecular $(CH_3)SiH$ and $(CH_3)_4Si$; Cat-CVD

1. Introduction

The hot wire chemical vapour deposition (HW-CVD) technique was introduced in 1979 by Wiesmann et al. [1]. They observed the thermal decomposition of SiH_4 at a heated tungsten filament hydrogenated amorphous-Si films. Jung et al. [2] have studied amorphous and crystalline SiC thin films deposited using radio frequency plasma enhanced chemical vapour deposition (RF-PECVD) system on corning glass and p type Si(1 0 0) wafer with a $SiH_4 + CH_4$ gas mixture. The silicon carbide (SiC) thin films are widely used as a composition material in many semiconductor devices, namely in solar cells [3], light emitting diode [4], color sensors [5], photo-modulator devices [6] metal–insulator–semiconductor structures. Crystalline silicon carbide (c-SiC) [7] thin film has attracted much interest for use in electrical and optoelectric devices, and circuits designed to operate at high temperature, high power, high frequency and high radiation environment due to its good electrical and mechanical characteristics such as electron mobility (1000 cm^2/Vs) [8], electron saturation velocity (2.0–2.7 × 10^7 cm/s) [9], breakdown electrical field (2–3 × 10^6) [10], high melting point and high thermal conductivity.

Growth and characteristics of SiC film from single source trimethylsilane, tetramethylsilane and hexamethyldisilane have been studied [11–13]. The physical and electrical characteristics of trimethylsilane doped low dielectric constant chemical vapour deposited oxides have also been studied [14]. Cathode glow polymerization of trimethylsilane and low hydrogen content trimethylsilane-based dielectric barriers deposited by inductively coupled plasma has been studied [15,16].

Koshi and co-workers [17,18] detected the catalytic decomposition of silane in a flow reactor by using time of flight mass spectrometery coupled with vacuum ultra violet (VUV) photoionization. In this paper, we report, catalytic-dissociation of trimethylsilane, and tetramethylsilane single source time of flight coupled VUV photoionization colli-

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2. Experimental

The schematically experimental apparatus is shown in Fig. 1. The experimental molecule trimethylsilane gas with He gas pressure is nearly 40 Torr (1 Torr = 133.322 Pa) are introduced as a molecular beam through a nozzle ($\Phi = 0.1$ mm) into a vacuum chamber. The trimethylsilane gas pressure is nearly 15 Torr in the chamber. These pressure are controlled by mass flow controller. The vacuum chamber is evacuated down to 1×10^{-7} Pa using a Turbo-Molecular Pump with rotary pump. The operating pressure in the vacuum chamber is nearly 3.0×10^{-4} Pa. In front the nozzle –orifice, a tungsten wire of 0.2 mm diameter and 15 cm in length is mounted to rings. The tungsten wire is resistively heated by a stabilized dc power supply. The temperature of the filament is measured to use resistivity of the hot filament condition.

The ionization is accomplished by photoionization at 10.5 eV (118 nm). Coherent VUV laser radiation (118 nm) is obtained by third harmonic generation, using tightly focused of 355 nm of Q-switched Nd-YAG laser into Xe gas cell. The gas pressure of Xe is 10 Torr. The VUV laser radiation is generated by nonlinear optical process to use Xe/Ar gas mixture cell adjusted to achieve optimum phase matching. The opposite side NO gas cell is attached. The pressure of NO is also nearly 10 Torr. The VUV laser radiation is directed into a photoionization cell containing NO gas. Since the ionization potential of NO molecule is 9.35 eV, the incident VUV laser radiation at 10.5 eV. The resultant photocurrent is monitored to measure the intensity of the VUV laser radiation is nearly $\sim 10^{10}$ photons/pulse.

The 118 nm laser radiation is dispersed through dispersive prism. The VUV laser radiation is focused via MgF_2 lens into molecular beam. The time of flight signals of the photoionized species are measured to use flight tube coupled MCP detector. The time of flight tube length is 20 cm. The MCP detector signal is fed to a digital oscilloscope (Tektronix TDS 520C) and transferred to a PC via GPIB interface. The TOF signal is plotted in intensity versus time of flight of ionized species.

No ionization signal is observed without the tripling medium, indicating that the ionization resulting from the multiphoton process by the UV (355 nm) is negligible. We also observed in our

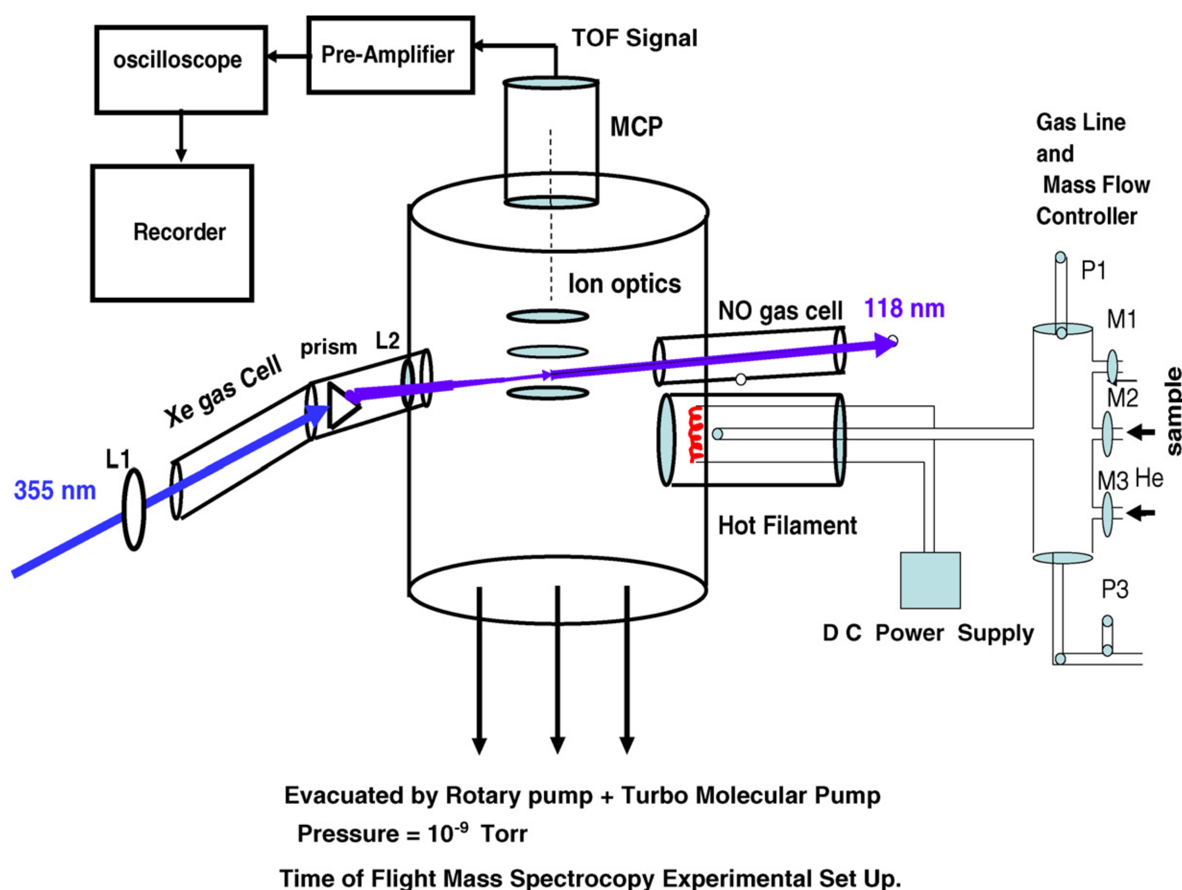

Fig. 1. Experimental setup of hot wire dissociation vacuum ultra violet time of flight mass spectroscopy. MCP, multichannel plate; RP, rotary pump; M1, M2 and M3 are mass flow controller of gases; PS, dc power supply, P1 and P2 are pressure gauges, etc.

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