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STW gas sensors using plasma-polymerized allylamine

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Abstract

Gas sensors generally consist of two major components: a gas recognition element which provides the specificity and selectivity of the measurement and a physical transducer which translates the gas absorption or desorption event into electronic signal. In this paper, plasma polymerized allylamine (PPAa) film is used as a gas recognition element and a surface transverse wave (STW) device is used as a physical transducer. It is confirmed that STW sensor devices coated with PPAa films provide high sensitivity for moisture. The STW sensor device with a 63 nm PPAa film provided twenty four times higher sensitivity than that of a non-coated STW device. In addition, the chemical structure of PPAa films is characterized by the FT-IR and the contact angle measurement.

Keywords: Plasma-polymerization; Gas sensor; Sensor; STW; Surface transverse wave; Sensitivity; Humidity

1. Introduction

Gas sensors generally consist of two major components: a gas recognition element which provides the specificity and selectivity of the measurement and a physical transducer which translates the gas absorption or desorption event into electronic signal. The combination of the gas recognition element and the physical transducer is very important for gas sensors. For the gas recognition elements, plasma-polymerization has been widely used to fabricate ultra thin films from a variety of volatile compounds without chemical solvents (dry process) and catalysts in coating process only by one-step [1].

For the physical transducers elastic devices such as quartz crystal microbalance (QCM) [2] and surface acoustic wave (SAW) devices [3,4] have been widely used. The QCM devices are based on thickness mode vibrations and the SAW devices are based on Rayleigh wave on the surface of the substrate. In these acoustic wave based gas sensors, higher operating frequencies make the sensitivity higher. SAW devices are suitable for higher operating frequencies in contrast of QCMs.

On the other hand, band-pass filters or resonators using the surface transverse wave (STW) have been utilized in specific communication equipments [5] as well as SAW devices. The STW is a shear horizontal (SH) wave which is traveling on quartz wafers and has advantages of high acoustic wave velocity and stable temperature characteristics. Then STW devices are very suitable for higher frequency applications. The STW is one of SH waves such as waves on 36° rotated *y*-cut $LiTaO_3$ substrates that are widely used for sensor applications [6]. A few studies on STW sensor devices have been published [7,8].

In this paper, a plasma-polymerized allylamine (PPAa) film [9–11] is used as a gas recognition element and an STW device is used as a physical transducer. When the PPAa films on the STW sensor devices detect gases, the oscillation frequency of the oscillator circuit using the STW sensor device can decline. The sensitivity of 240 MHz STW sensor devices coated with PPAa films with different thicknesses has been evaluated using moisture concentration. The chemical structure of a PPAa film has been characterized by the FT-IR and the contact angle measurement.

2. Plasma-polymerization

For plasma-polymerization, the plasma-polymerization equipment Model BP-1 of Samco International Co. (Kyoto, Japan) was used [9,12]. The plasma-polymerized films were deposited on one side of the STW devices. The schematic diagram of plasma-polymerization equipment was illustrated

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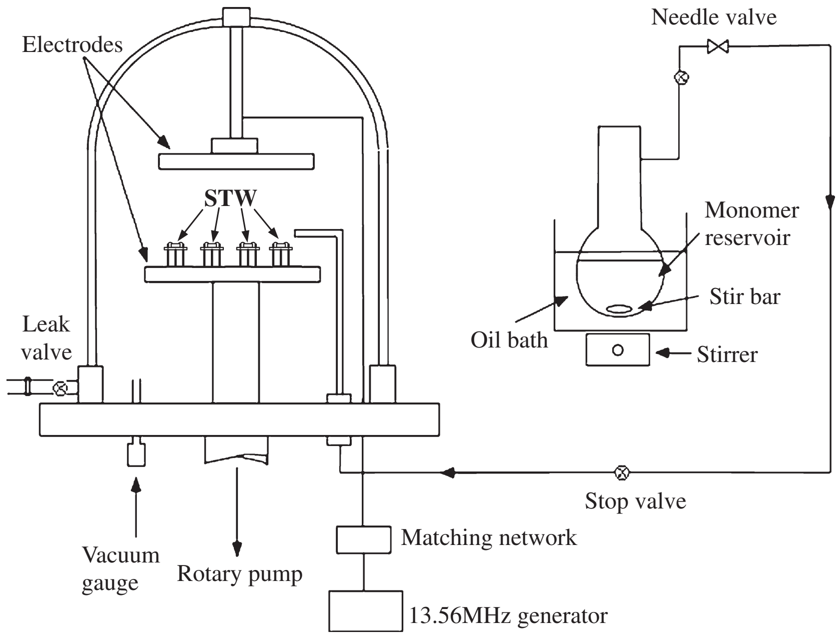

Fig. 1. Schematic diagram of plasma-polymerization equipment.

in Fig. 1. Prior to plasma-polymerization, the STW devices were treated by plasma sputtering for 5 s under 100 W of RF power and 100 Pa of He pressure. Vapor pressure of the monomer and the RF power of the glow discharge are two of the most important controllable parameters in plasma-polymerization. In this experiment, vapor pressure of the monomer and the RF power were settled at 100 Pa and 100 W, respectively. The monomer was vaporized at a constant liquid

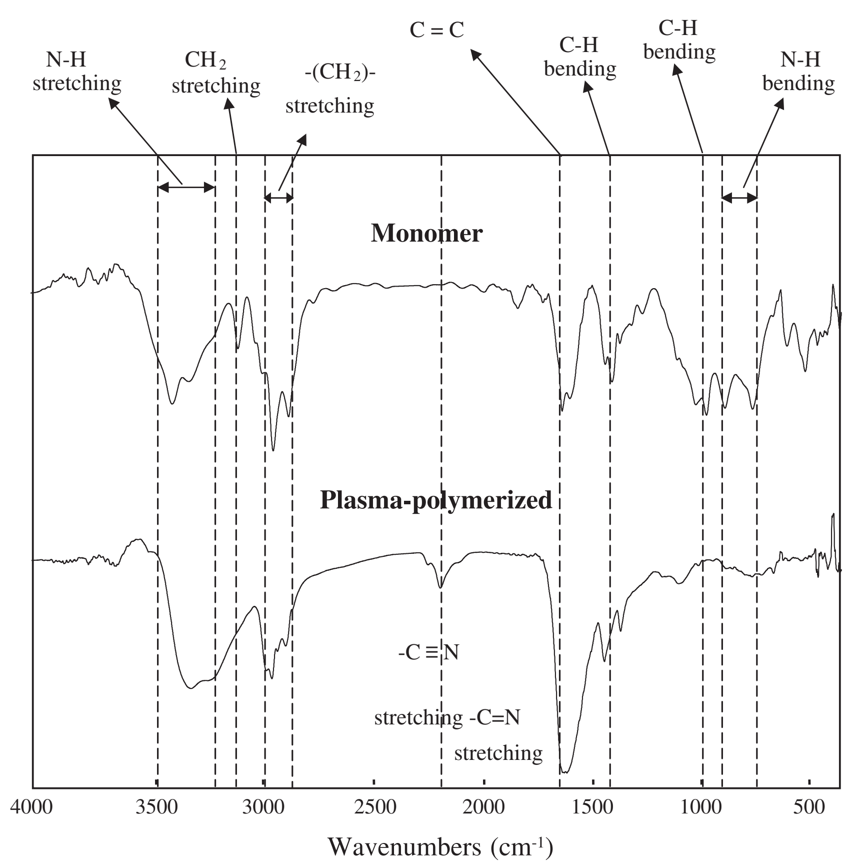

Fig. 2. FT-IR transmission spectrum of allylamine monomer and PPAa film.