

Deposition of Plasma-Polymerized Acetylene by an Intense Pulsed RF Plasma Source

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Abstract—An inductively coupled, intense, pulsed RF plasma source deposited plasma-polymerized acetylene at a rate of 127 Å per discharge. The potassium bromide (KBr) substrate was located 18-cm downstream from the RF coil. A puff valve admitted parent acetylene gas just before the transient RF current was applied. Fourier Transform Infrared (FTIR) spectra showed that carbon-to-carbon double bonds were formed. SEM images showed that the film thickness after 79 discharges was 1 μm. A photodiode showed substantial light emission for about 30 μs during each discharge.

I. INTRODUCTION

PULSED plasma sources have been investigated for use in thin film deposition [1]–[5]. Advantages include the accurate control of substrate temperature, production of layered structures, production of new materials, reduced UV emission, additional control of free radical production rate, high degree of dissociation of the parent gases, and the fact that a properly selected pulse rate eliminates suspended macroscopic particles as may appear in steady-state parallel-plate reactors [6], [7]. Previously [8], we described a pulsed plasma device that produced packets of drifting plasma. In this paper we describe some of the plasma polymerization properties of this device when acetylene was used as the source gas.

II. EXPERIMENTAL SETUP

A detailed description of the device was given previously [8]. Details that are important for this work are shown in Fig. 1. A puff valve delivered the monomer gas (C_2H_2) just before each discharge, and a 1.9-μF capacitor, charged to 20 kV, energized the RF coil. The resulting plasma packet impinged on the KBr pellet that was mounted to a Plexiglas and stainless-steel stage. The KBr substrate was located 18-cm downstream from the center of the RF coil. The photodiode with collimator viewed the region shown cross-hatched in Fig. 1. The photodiode was a Motorola Model MRD500, whose circuit was de-

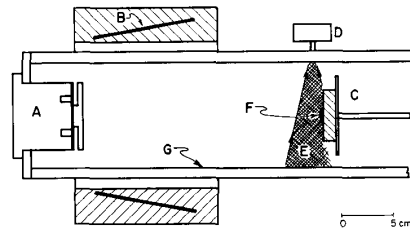


Fig. 1. Apparatus: A = Puff valve. B = RF coil. C = Substrate holder. D = Photodiode with collimator. E = Region viewed by photodiode. F = KBr substrate. G = Pyrex vacuum vessel.

scribed in earlier work [8]. The RF current was measured with a Rogowski coil with passive integrator [9]. The deposited film was analyzed with a scanning electron microscope and an FTIR spectrometer.

III. RESULTS

Fig. 2 shows the sequence of events for each discharge from the pulsed plasma source. At $t = 0$, the puff valve was energized; at $t = 400 \mu s$ the RF coil was energized by a damped sinusoidal current with a frequency of 290 kHz and maximum value of 50 kA. At $t = 420 \mu s$ substantial light was emitted from near the substrate. Light was emitted for a duration of about 30 μs. From previous work with CF_4 gas [8], we estimate that the acetylene pressure existing before the RF coil was energized was about 500 mtorr.

After exposure to 79 discharges at a repetition rate of 1 discharge per minute, the KBr pellet was examined by SEM and FTIR. The repetition rate was limited by the power supply used to charge the 1.9-μF capacitor and by the pumping rate of the oil diffusion pump used to evacuate the chamber. Ambient pressure before energizing the puff valve was about 5×10^{-5} torr.

Fig. 3 is an SEM photograph showing that the deposited material was about 1-μm thick, indicating an average deposition rate of about 127 Å per discharge. In Fig. 3, the polymer film has been lifted away from the KBr substrate to reveal the 1-μm film thickness. The rolling texture of the polymer reflects the underlying graininess of the KBr substrate.

Fig. 4 shows the FTIR spectrum, which indicates that carbon-to-carbon double bonds were present, as well as carbon-to-hydrogen bonds.

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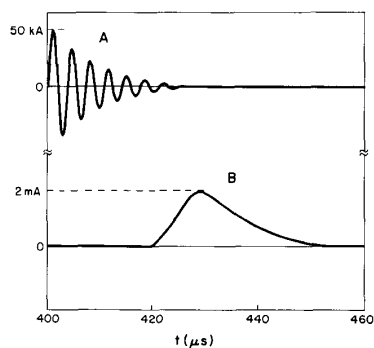


Fig. 2. Sequence of events. A = RF current, and B = photodiode current.

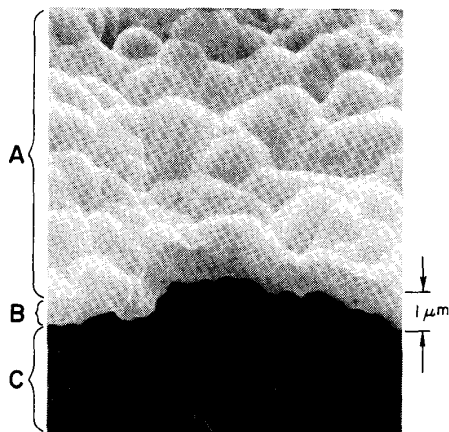


Fig. 3. SEM photograph: A = Deposited polymer, B = edge of torn polymer, and C = underlying KBr substrate.

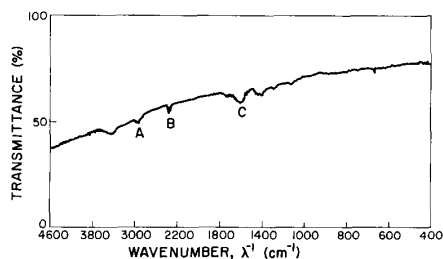


Fig. 4. FTIR spectrum: A = Water, B = carbon to hydrogen bonds, and C = carbon-to-carbon double bonds.

IV. DISCUSSION

Polymerization is known to continue during the off period of a pulsed reactor due to the source gas reacting with radicals on the previously deposited film, and due also to the finite lifetime of radicals in the gas phase [5]. We do not know how much deposition took place during the glow, nor how much took place as the source gas was being pumped out.

V. CONCLUSIONS

An intense, pulsed RF plasma source produced thin films of plasma-polymerized acetylene. The deposition

rate was about 127 Å per discharge. The FTIR spectrum showed that carbon-to-carbon double bonds were present.

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