Materials Science and Engineering B 119 (2005) 268–273

MATERIALS SCIENCE & ENGINEERING B

www.elsevier.com/locate/mseb

Packaging barrier films deposited on PET by PECVD using a new high density plasma source

John Madocks*, Jennifer Rewhinkle, Loren Barton

Applied Process Technologies, Inc., 546 East 25th Street,Tucson, AZ 85713, USA

Received 7 June 2004; received in revised form 20 October 2004; accepted 9 December 2004

Abstract

Barrier films for packaging applications are deposited by plasma enhanced chemical vapor deposition (PECVD) on PET film using a new, high density plasma source. The new source, termed the Penning Discharge Plasma source, implements a novel magnetic field/electrode configuration that confines the electron Hall current in an endless loop adjacent to the substrate. By confining the Hall current, a dense, uniform plasma is created and sustained over wide substrates. The result is high rate deposition at low substrate temperatures. The water vapor permeation of SiO_2 barrier films is reported as well as deposition rate, coating thickness and other film properties.

Keywords: PECVD; Barrier film; Roll to roll; High density plasma; SiO_x coatings

1. Introduction

The demand for clear water vapor and oxygen barrier packaging films is growing due to needed properties, such as recycle-ability, microwave-ability and visibility of contents [1]. These films are most commonly SiO_2 or Al_2O_3, deposited by physical vapor deposition (PVD) techniques, such as reactive evaporation and sputtering. An alternative deposition method, plasma enhanced chemical vapor deposition (PECVD), is less common but has several advantages over PVD:

- PECVD films are highly adherent to the substrate and have improved stretch-ability and flexibility to withstand post converting and laminating operations [2].
- PECVD is a relatively low heat process and can deposit on substrates with low heat resistance such low density polyethylene and polypropylene [2].
- PECVD can deposit thick, relatively low stress films.
- PECVD is an energy efficient and materials efficient process.

In the semiconductor and display markets PECVD is routinely used to deposit metal oxides and nitrides. In these markets PECVD is preferred over reactive sputtering for depositing reactive and insulating films. In the large area substrate markets, such as packaging barrier film, PECVD penetration is very limited. There have been several reasons for this:

- PECVD deposition rate has not been competitive with PVD techniques. For instance, in clear barrier packaging film, PECVD rates have not been economical compared to reactive aluminum evaporation metalizing.
- PECVD reactors have been relatively complex and expensive often involving microwave or RF power supplies.
- PECVD reactor electrodes tend to coat up in a long roll to roll (R2R) process. In a semiconductor or display application, frequent etch-back cycles are used to keep the electrodes clean. The R2R production process does not have this luxury.
- Coating uniformity has been difficult to achieve for large area substrates.

Plasma source technology can make a big difference in the commercial success of a process. An example of this is magnetron sputtering. Prior to the invention of the magnetron

* Corresponding author. Tel.: +1 520 882 5100x24; fax: +1 520 882 5165.
E-mail address: jm2docks@appliedpt.com (J. Madocks).

0921-5107/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.mseb.2004.12.080

cathode, diode sputtering was infrequently used due to drawbacks, such as low deposition rate, poor film quality and poor uniformity. With the invention of the magnetron this situation changed dramatically. Today magnetron sputtering is used to create billions of dollars in products ranging from architectural glass to DVD disks.

2. The Penning Discharge Plasma (PDP) source

The Penning Discharge Plasma source is a magnetically confined plasma source optimized for PECVD. The source has been termed the PDP source because the basic configuration of the cathodes and anode, in relation to the magnetic and electric fields, is similar to a Penning Cell [3]. Fig. 1 shows a section view of the PDPS with the magnetic and electric fields schematically overlaid. Fig. 2 shows an isometric view of the PDPS with a flexible web substrate wrapped over the electrode rolls.The PDP source has several features and benefits that make it effective for large area PECVD:

(1) *Deposition and morphology uniformity*: The facing cathode electrodes and dipole magnetic field confine the electron Hall current in the center of the gap. This produces a uniform plasma enabling uniform coating of wide web substrates. The uniformity obtained is analogous to a magnetron sputter cathode, as the same Hall current confinement principle is at work. In a magnetron sputter cathode, the racetrack Hall current allows architectural glass over 3 m wide to be coated with better than 5% uniformity. Though the Hall confinement of the PDP source is distant from the cathode surface, the same fundamental benefit of a constant impedance plasma over the full source applies. This is an improvement over existing PECVD source technologies.

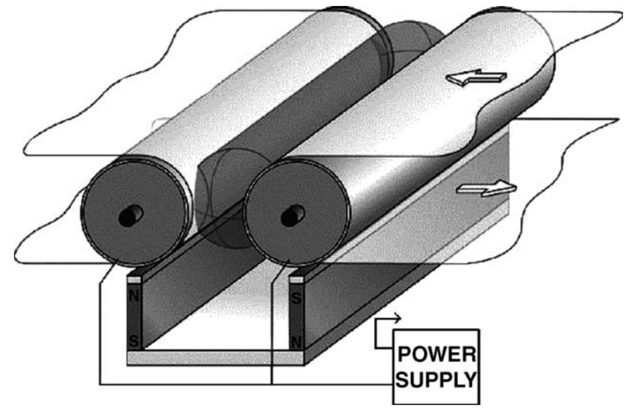

Fig. 2. An isometric view of the PDP source for flexible substrates.

(2) *Low temperature process*: The PDP source is a low impedance plasma that operates at low pressures (10 mTorr). This results in low neutral particle and ion temperatures and high electron temperatures. The neutral particle and ion temperatures are close to room temperature. The high electron temperature efficiently produces radicals and ions for deposition. A second characteristic of the PDP source is, unlike parallel plate RF, the dual cathode and magnetic field configuration minimizes hot secondary electron bombardment on the substrate. The result is high rate, high power PECVD at reduced substrate temperatures.

(3) *High deposition rate*: As illustrated in the experimental results, the PDP source achieves high deposition rates at low powers. There are several reasons for this:

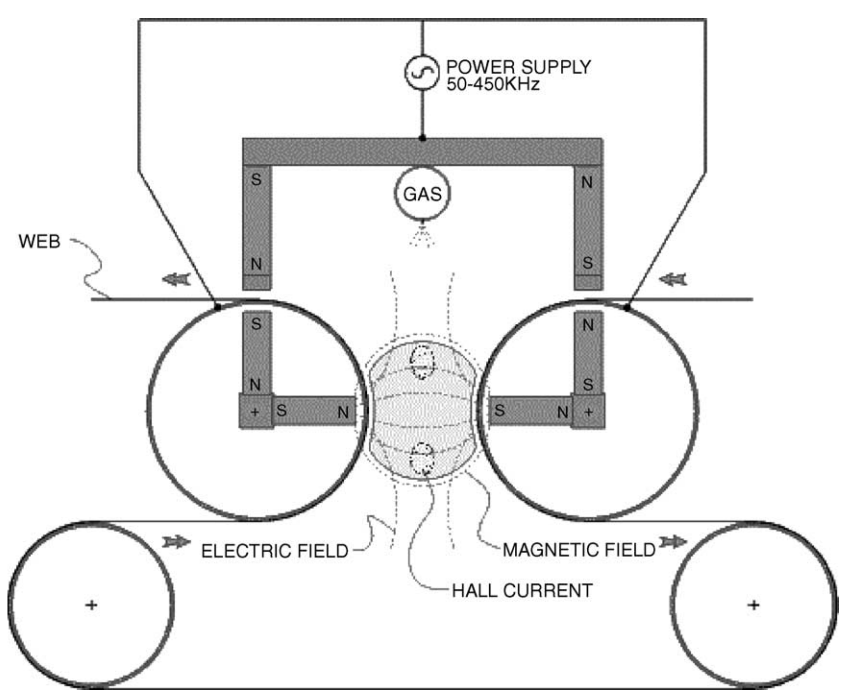

Fig. 1. Schematic view of the PDP source.