

ABSTRACT

A method of forming material layers on a substrate using atomic gas is provided. A substrate is heated to an elevated temperature and is exposed to an atomic gas. The atomic gas reacts at a surface of the substrate to form a material layer thereon. The source of atomic gas preferably comprises a molecular gas source operatively coupled to a remote microwave plasma system that dissociates the molecular gas into highly reactive atomic gas. Gate quality silicon dioxide, oxynitride and silicon nitride may be formed by the dissociation of  $O_2$ ,  $O_2$  and  $N_2$  or  $NH_3$ , and  $N_2$  or  $NH_3$ , respectively, at reduced temperatures (e.g., about 600-650°C). Because of the reduced formation temperatures, a uniform heating mechanism such as a ceramic heater may be employed for substrate heating so that a more uniformly-thick material layer results. To reduce recombination of gas atoms into molecular gas, the path length between the atomic gas source and the substrate is reduced, or an inert gas may be used to dilute the atomic gas so as to spatially separate gas atoms. A portion of the path between the atomic gas source and the substrate also may be coated with a protective coating to prevent gas atom recombination.

