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APPLICATION NUMBER: *09/145,323*
FILING DATE: *September 01, 1998*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US09/145,323*

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PATENT APPLICATION

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(Printed name of person mailing paper or fee)
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09/145323 09/01/98

CASE 1-1-1

TITLE Pulse DC Reactive Sputtering Method

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

NEW APPLICATION UNDER 37 CFR 1.53(b)

Enclosed are the following papers relating to the above-named application for patent:

Specification
4 Informal sheets of drawing(s)
Information Disclosure Statement

CLAIMS AS FILED				
	NO. FILED	NO. EXTRA	RATE	CALCULATIONS
Total Claims	18 – 20 =	0	x $22 =	$0
Independent Claims	3 – 3 =	0	x $82 =	$0
Multiple Dependent Claim(s), if applicable			$270 =	$0
Basic Fee				$790
			TOTAL FEE:	$790

Please file the application and charge **Lucent Technologies Deposit Account No. 12-2325** the amount of $790, to cover the filing fee. Duplicate copies of this letter are enclosed. In the event of non-payment or improper payment of a required fee, the Commissioner is authorized to charge or to credit **Deposit Account No. 12-2325** as required to correct the error.

The Assistant Commissioner for Patents is hereby authorized to treat any concurrent or future reply, requiring a petition for extension of time under 37 CFR § 1.136 for its timely submission, as incorporating a petition for extension of time for the appropriate length of time if not submitted with the reply.

Please address all correspondence to **Docket Administrator (Room 3C-512), Lucent Technologies Inc., 600 Mountain Avenue, P. O. Box 636, Murray Hill, New Jersey 07974-0636.** However, telephone calls should be made to me at 908-582-3246.

Respectfully,

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Date: 9-1-98

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Miller 1-1-1

PULSE DC REACTIVE SPUTTERING METHOD FOR FABRICATING PIEZOELECTRIC RESONATORS

Background of the Invention

1. Field of the Invention

The invention relates to piezoelectric resonators. More particularly, the invention relates to deposition techniques used in fabricating piezoelectric resonators and the piezoelectric resonators made by those deposition techniques.

2. Description of the Related Art

Piezoelectric resonators are devices comprising a wafer of piezoelectric material such as quartz, zinc oxide (ZnO), aluminum nitride (AlN) or ceramic material mounted or otherwise formed on a substrate (e.g., silicon or aluminum oxide). Upon the application of a voltage to the piezoelectric material, e.g., via electrodes, the piezoelectric material vibrates in a certain vibrational mode depending on the orientation or polarization of the piezoelectric material and at a certain (resonant) frequency depending on the thickness of the piezoelectric material.

Piezoelectric resonators provide clearly defined mechanical resonances and are useful, e.g., for discriminating between signals based on frequency diversity (i.e., a filter). Also, piezoelectric resonators are useful in providing stable frequency signals, e.g., as a frequency stabilizing feedback element in an oscillator circuit.

Typically, the resonant frequency of the piezoelectric material is inversely proportional to its thickness. Accordingly, for piezoelectric resonators to operate at high frequencies, e.g., frequencies greater than approximately 700 Megahertz (MHz), the thickness of the piezoelectric material must be reduced to the point of depositing a thin piezoelectric film on the substrate. Conventional deposition techniques for depositing such piezoelectric films include, e.g., chemical vapor deposition (CVD) and sputter deposition such as RF sputter deposition.

Sputter deposition involves a vacuum deposition process in which a sputtering target is bombarded with ions, typically an ionized noble gas such as argon, and the atoms of the target material are mechanically freed by momentum transfer and available for coating a nearby substrate. Suitable target materials include, e.g., aluminum, silicon and titanium. In a reactive sputtering process, a reactive gas is introduced into the deposition chamber and reacts with the target material to produce a target insulating film that subsequently is sputtered onto the substrate or reacts with freed target material to form a coating material that is sputtered onto the substrate. Suitable reactive gases include oxygen, nitrogen, ammonia and hydrogen.

In DC reactive sputtering, the target material and the reactive gas react in a plasma to produce the coating material. The plasma is formed by the noble gas when an direct current (DC) electric potential is applied within the sputtering chamber. For example, aluminum atoms from an aluminum target react with nitrogen (reactive gas) at the target to produce an insulating film of aluminum nitride (AlN), which is sputtered onto the substrate with ions of argon (noble gas). Other suitable coatings include, e.g., oxides such as aluminum oxide (Al_2O_3), carbides such as silicon carbide (SiC), and nitrides such as titanium nitride (TiN) or zinc oxide (ZnO).

However, sputter deposition and reactive sputtering techniques including DC reactive sputtering often do not provide adequate deposition rates. Accordingly, such techniques take longer to perform, which is undesirable from the standpoint of required processing time and ultimately is undesirable from an economic standpoint. Also, the relatively lengthy deposition period increases the introduction of impurities into the piezoelectric film being deposited.

One specific type of reactive sputtering that often is used in, e.g., silicon processing methods, is pulse DC reactive sputtering. Since the target insulating film is an insulator (e.g., AlN), the noble gas ions tend to accumulate on its surface, reducing the sputter rate and ultimately terminating the sputter process. In pulse DC reactive sputtering, the electric potential formed between the cathode and the anode in the chamber is reversed periodically to prevent charge accumulation on the target insulating film. More specifically, the positive portion of the applied voltage neutralizes accumulation of the noble gas ions on the surface of the target insulating film, and the negative portion of the applied voltage, if sufficient, causes ions from the noble gas to impinge upon the target insulating film formed on the target material, physically removing ions thereof and allowing them to accumulate on the substrate. This forms the deposited layer or coating.

In addition to silicon processing, pulse DC reactive sputtering techniques also are useful in depositing, e.g., wear resistant coatings such as tungsten carbide (WC) or titanium nitride (TiN) on, e.g., drill bits, wear plates and valve spindles. See generally, e.g., U.S. Pat. Nos. 5,651,865 and 5,718,813. In pulse DC reactive sputtering, the major qualitative concerns are the ultimate film constituency (i.e., reduced impurities introduced into the deposited film), film stress and film texture. Film texture generally characterizes the physical structure of the film resulting from the shape, arrangement and proportions of its components.

With respect to the deposition of thin piezoelectric films such as aluminum nitride (AlN), an important consideration includes the crystal orientation of the atoms within the final deposited film. That is, the crystal structure cannot be amorphous; it must be of a single crystal nature. This is because piezoelectricity occurs from the alignment of the atomic dipoles within the film, and an amorphous film produces random dipole moments with no macroscopic response. Also, it is desired that the film orientation be perpendicular to the substrate to facilitate the launching of longitudinal waves in a structure. It is believed that current deposition techniques are concerned primarily with deposition rates and consideration such as crystal structure are not taken into account.

Accordingly, it is desirable to have available an improved technique for depositing thin films of piezoelectric material such as aluminum nitride (AlN) on a substrate that provides piezoelectric films with improved control of film constituency, stress and texture.

Summary of the Invention

The invention is embodied in a pulse DC reactive sputtering method for thin film deposition. The inventive method is used, e.g., for depositing thin films of piezoelectric

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