如何选用湿度传感器

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摘　要：讨论湿度传感器的三种选择该篇对于电容性、电阻性和热传导率原理的湿度传感器的讨论中也涉及到它们的优点、缺点和应用。

当你选一台湿度传感器时，一定要注意以下这些重要的规格参数：

- 精度
- 重复性
- 互换性
- 长期稳定性
- 抗结露的能力
- 对化学制品和物理污染物的阻力
- 尺寸
- 封装
- 价格

还有非常重要的因素是：传感器的替换、安装和本地校准以及信号处理的可靠性和复杂程度与数据采集电路。综上所述，用户需要有一种适合大部分应用场合和性能更佳的湿度传感器。

常用的湿度定义是绝对湿度、露点和相对湿度。

电容湿度传感器

相对湿度：

电容相对湿度（RH）传感器（见

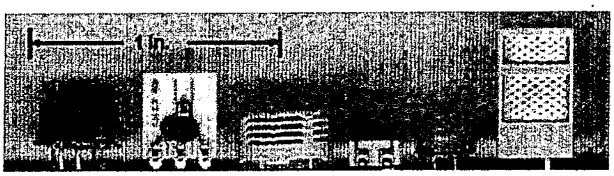

图1. 应用广泛的电容式湿度传感器。图中为几个制造商的产品。

图1）被广泛地用在工业、商业和气侯遥感应用中。

电容传感器主体是封装在片基上中间填充聚合体或金属氧化物的两个电极。表层感湿电极多孔透水汽以保护它免遭污染和结露。片基一般由玻璃、陶瓷品或硅组成。电容湿度传感器上的容值几乎与周围的环境湿度成正比，该容量的典型变化为0.2--0.5pF对应1%的湿度变化，而

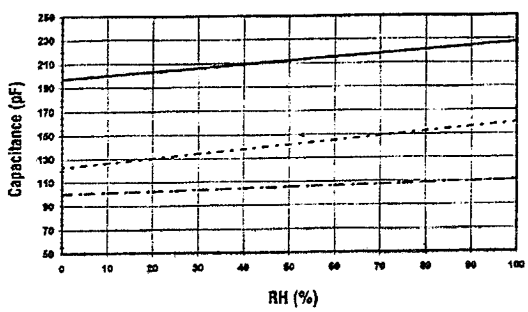

表 1

大多数电容值在100-500pF之间（对应湿度50%/25℃），电容传感器具有低温度系数，耐高温（高达200℃），完全可抵御结露以及化学气体。对于63%的RH阶跃响应时间为30-60秒。

电容湿度传感器的生产技术得益于半导体制造业，可以获得很小的漂移和迟滞。在薄膜电容基片上也可集成信号处理电路。常用一个CMOS定时器产生脉冲而得到一个线性电压输出（图1）

电容传感器的精度经过两点（5%-95%RH）校准可以达到±2%。电容传感器受引线电容影响不能长距离感测，实际距离小于10英尺。

直接互换也是一个问题，除非传感器是激光修正或使用微处理器技术。这些办法可以补偿100-500pF。

露点：

薄膜电容在低RH处信号是非线性和离散的，但是具有稳定性好和长期漂移小的特点，使用微处理器和非易失性存储器可以提供测量露点的好办法，大大降低露点计成本，并用于冷暖空调和气象遥测上。

露点输出和RH一样也是电压。微处理器记录在-40℃-27℃的20个露点数据，露点数据是由追溯NIST的冷镜露点仪作参考，输出电压对应传感器存储在仪器EPROM里的露点/霜点数据，微处理器利用这些数据参照干球温度进行线性差值计算水汽压力。

一旦水汽压力确定了，露点温度便可从储存在EPROM的热力学方程式计算出。精度为±2℃（-40℃-7℃），±1℃（-7℃-27℃），年漂移小于1.5℃，这种方法测量露点已经广泛使用在那些使用露点仪成本过高的场合。

电阻型湿度传感器

Choosing Of A Humidity Sensor

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This discussion of the operating principles of capacitive, resisitive, and thermal conductivity humidity sensors also addresses their advantages, disadvantages, and applications.

The most important specifications to keep in mind when selecting a humidity sensor are:

- Accuracy
- Repeatability
- Interchangeability
- Long-term stability
- Ability to recover from condensation
- Resistance to chemical and physical contaminants
- Size
- Packaging
- Cost effectiveness

Additional significant long-term factors are the costs associated with sensor replacement, field and in-house calibrations, and the complexity and reliability of the signal conditioning and data acquisition (DA) circuitry. For all these considerations to make sense, the prospective user needs an understanding of the most widely used types of humidity sensors and the general trend of their expected performance. Definitions of absolute humidity, dew point, and relative humidity are provided in the sidebar, Humidity Basics.

Capacitive Humidity Sensors Relative Humidity.

Capacitive relative humidity (RH) sensors (see Photo 1) are widely used in industrial, commercial, and weather telemetry applications.

They consist of a substrate on which a thin film of polymer or metal oxide is deposited between two conductive electrodes. The sensing surface is coated with a porous metal electrode to protect it from contamination and exposure to condensation. The substrate is typically glass, ceramic, or silicon. The incremental change in the dielectric constant of a capacitive humidity sensor is nearly directly proportional to the relative humidity of the surrounding environment. The change in capacitance is typically 0.2–0.25 pF for a 1%RH change, while the bulk capacitance is between 100 and 500 pF at 50% RH at 25. Capacitive sensors are characterized by low temperature coefficient, ability to function at high temperatures (up to 200), full recovery from condensation, and reasonable resistance to chemical vapors. The response time ranges from 30 to 60 s for a 63% RH step change.

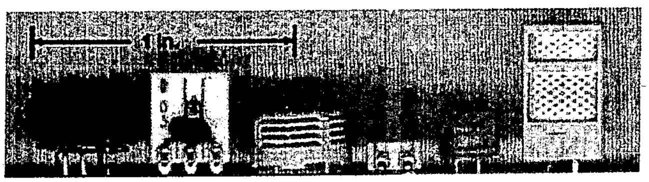

Photo 1. Capacitive RH sensors are produced in a wide range of specifications, sizes, and shapes including integrated monolithic electronics. The sensors shown here are from various manufacturers.

State-of-the-art techniques for producing capacitive sensors take advantage of many of the principles used in semiconductor manufacturing to yield sensors with minimal long-term drift and hysteresis. Thin film capacitive sensors may include monolithic signal conditioning circuitry integrated onto the substrate. The most widely used signal conditioner incorporates a CMOS timer to pulse the sensor and to produce a near-linear volt age output (see Figure 1).

The typical uncertainty of capacitive sensors is ±2%RH from 5% to 95% RH with two-point calibration. Capacitive sensors are limited by the distance the sensing element can be located from the signal conditioning circuitry, due to the capacitive effect of the connecting cable with respect to the relatively small capacitance changes of the sensor. A practical limit is <10 ft

Direct field interchangeability can be a problem unless the sensor is laser trimmed to reduce variance to ±2% or a computer-based recalibration method is provided. These calibration programs can compensate sensor capacitance from 100 to 500 pF.

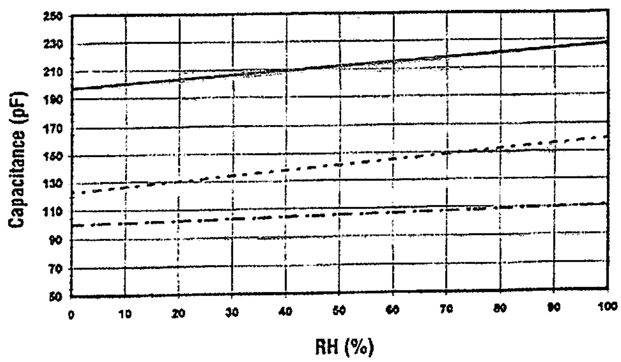

Figure 1. A near-linear response is seen in this plot of capacitance changes vs. applied humidity at 25 ℃. The term "bulk capacitance" refers to the base value at 0% RH.

Dew Point

Thin film capacitance-based sensors provide discrete signal changes at low RH, remain stable in long-term use, and have minimal drift, but they are not linear below a few percent RH. These characteristics led to the development of a dew point measuring system incorporating a capacitive sensor and microprocessor-based circuitry that stores calibration data in nonvolatile memory. This approach has significantly reduced the cost of the dew point hygrometers and transmitters used in industrial HVAC and weather telemetry applications.

The sensor is bonded to a monolithic circuit that provides a voltage output as a function of RH. A computer-based system records the voltage output at 20 dew point values over a range of -40℃-27℃. The reference dew points are confirmed with a NIST-traceable chilled mirror hygrometer. The voltage vs. dew/frost point values acquired for the sensor are then stored in the EPROM of the instrument. The microprocessor uses these values in a linear regression algorithm along with simultaneous dry-bulb temperature measurement to compute the water vapor pressure. Once the water vapor pressure is determined, the dew point temperature is calculated from thermodynamic equations stored in EPROM. Correlation to the chilled mirrors is better than ±2℃ dew point from -40℃-27℃ and ±1℃ from -7℃ to 27℃. The sensor provides long-term stability of better than 1.5 dew point drift/yr. Dew point meters using this methodology have been field tested extensively and are used for a wide range of applications at a fraction of the cost of chilled mirror dew point meters.

Resistive Humidity Sensors

Resistive humidity sensors (see Photo 2) measure the change in electrical impedance of a hygroscopic medium such as a conductive polymer, salt, or treated substrate.

The impedance change is typically an inverse exponential relationship to humidity (see Figure 2).

Figure 2. The exponential response of the resistive sensor, plotted here at 25, is linearized by a signal conditioner for di-

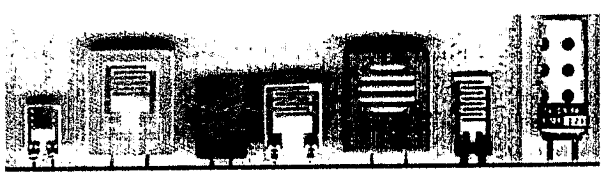

Photo 2. Resistive sensors are based on an interdigitated or bifilar winding. After deposition of a hydroscopic polymer coating, their resistance changes inversely with humidity. The Dunmore sensor (far right) is shown 1/3 size.

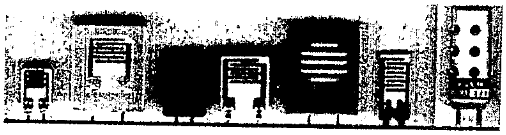

图 2

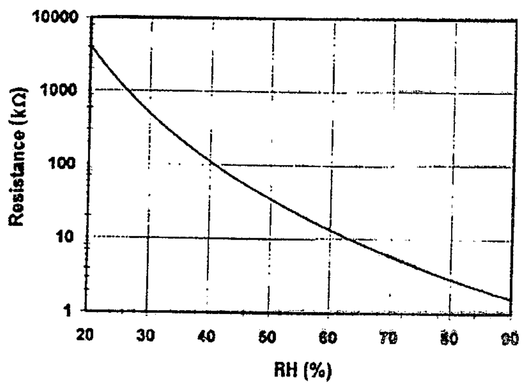

表 2

测量吸湿介质如导电聚合物、盐和基底的阻抗阻抗的典型变化呈反指数曲线（图 2).

电阻传感器通常包括金属电极，电极靠光刻技术沉积在基体上在一个塑料或玻璃圆筒腐蚀金属丝形成。这个基体被盐或导电性聚合物涂上。当它被溶解或浸没在液体中，它作为媒介均匀地传导给传感器。同时，这个基体也对化学制品起反应（比如酸）。传感器吸收水蒸气后离解，造成在电导率的增加。对于 63%RH 的阶跃响应时间为 10-30 秒。典型元素的阻抗范围变化从 1K Ω 到 100M Ω。

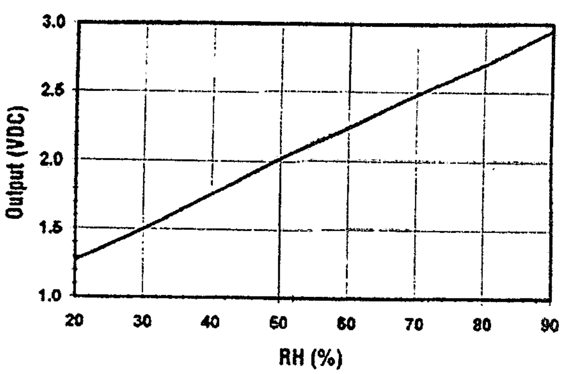

表 3

多数电阻传感器使用对称交流电压激励，没有直流分量以防止传感器的极化。起作用的直流电压信号被转换和放大为直流信号而与扫描、放大、线性或 A/D 转换电路匹配（见图 3）。

常用的激励频率是从 30 赫兹到 10 千赫。

电阻传感器不是纯阻抗型的，电容大于 10-100M Ω 时相当于阻抗特性。电阻传感器的好处是他们的互换性好，通常在 2%RH 之内，校准比较容易，设置不用湿气标准装置。电阻传感器的使用温度范围从 -40℃ 到 100℃ 。

在住宅和商业环境里，这些传感器的估计寿命大于5年，但对化工气体和其它污染物（比如油薄雾）也会导致过早的失效。有些使用水溶涂层的电阻传感器缺点是它们的漂移大（当暴露在结露中）。如电阻传感器安装在一个温度波动(>10℃)大的环境时温度影响很大。必须做温度补偿以保证准确性。体积小、成本低、互换性好、长期稳定强使这些电阻传感器适合在工业控制和商业住宅应用。

首批大量生产的湿度传感器之一是Dunmore 型号，由 NIST 在 40 年代开发使用至今。它包括把导线双重绕在用聚乙烯醇的一个塑料圆筒混合物上，然后涂上锂溴化物或锂氯化物。改变锂溴化物或锂氯化物的浓度能获得在 20%-40%RH 量程内的高分辨率传感器。在非常低的 RH 时，如在 1%-2%RH 范围，准确度可达到 0.1%。Dunmore 传感器广泛被应用在空调精确控制以维护计算机室的环境，也可在电信传输线，天线和波导管使用。

最新的发展是在电阻湿度传感器里使用陶瓷涂层以克服结露发生的环境局限。传感器包括一个陶瓷基体和由光刻过程制造的贵重金属电极。基体表面用一个导电性聚合体 / 陶瓷粘合剂混合物涂层，并且另外安装一个防护塑料外壳和尘土过滤器。

合成材料是液状陶瓷粉末，涂上合成的空气干燥材料后，将传感器作加热处理，这个过程形成一个抗结露的非水溶厚膜涂层（参见图 4）。

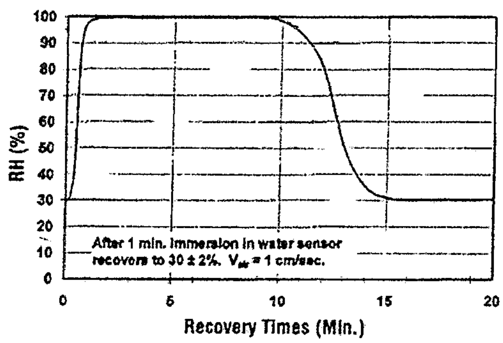

表 4

制造过程产出的传感器具有 3%RH 的互换性（在 15%--95%RH 内）。经过微处理器处理精度可达± 2%RH。恢复时间从充分结露到30%是几分钟。当使用信号处理电路，传感器电压产品与相对湿度成线性比例关系。

热传导湿度传感器

这些传感器(参见照片 3) 通过定量测量干燥空气和有水蒸气压的空气之间的热传导差来测量绝对湿度。

control.

Resistive sensors usually consist of noble metal electrodes either deposited on a substrate by photoresist techniques or wire-wound electrodes on a plastic or glass cylinder. The substrate is coated with a salt or conductive polymer. When it is dissolved or suspended in a liquid binder it functions as a vehicle to evenly coat the sensor. Alternatively, the substrate may be treated with activating chemicals such as acid. The sensor absorbs the water vapor and ionic functional groups are dissociated, resulting in an increase in electrical conductivity. The response time for most resistive sensors ranges from 10 to 30 s for a 63% step change. The impedance range of typical resistive elements varies from 1K Ω to 100M Ω.

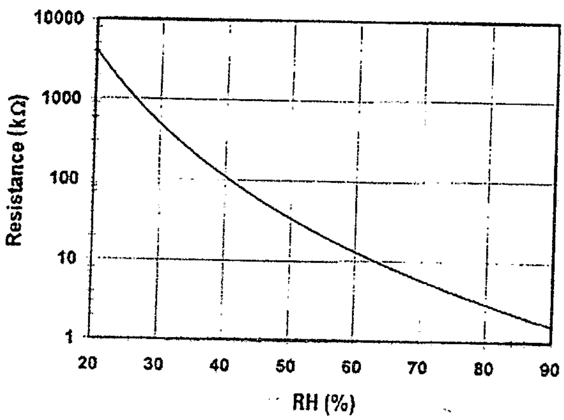

Figure 2. The exponential response of the resistive sensor, plotted here at 25 ℃, is linearized by a signal conditioner for direct meter reading or process control.

Most resistive sensors use symmetrical AC excitation voltage with no DC bias to prevent polarization of the sensor. The resulting current flow is converted and rectified to a DC voltage signal for additional scaling, amplification, linearization, or A/DRconversion (see Figure 3).

Nominal excitation frequency is from 30 Hz to 10 kHz.

The "resistive" sensor is not purely resistive in that capacitive effects 10-100M Ω makes the response an impedance measurement. A distinct advantage of resistive RH sensors is their interchangeability, usually within ±2% RH, which allows the electronic signal conditioning circuitry to be calibrated by a resistor at a fixed RH point. This eliminates the need for humidity calibration standards, so resistive humidity sensors are generally field replaceable. The accuracy of individual resistive humidity sensors may be confirmed by testing in an RH calibration chamber or by a computer-based DA system referenced to standardized humidity-controlled environment. Nominal operating temperature of resistive sensors ranges from -40℃ to 100℃.

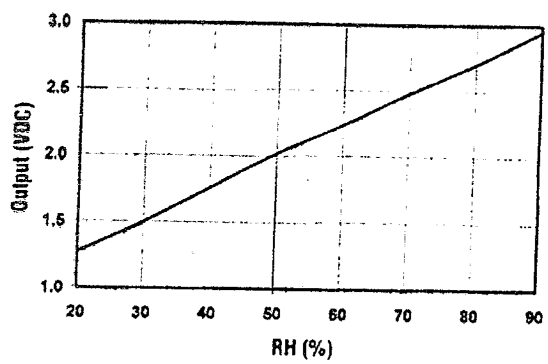

Figure 3. Resistive sensors exhibit a nonlinear response to changes in humidity. This response may be linearized by analog or digital methods. Typical variable resistance extends from a few kilohms to 100 MV.

In residential and commercial environments, the life expectancy of these sensors is >>5 yr, but exposure to chemical vapors and other contaminants such as oil mist may lead to premature failure. Another drawback of some resistive sensors is their tendency to shift values when exposed to condensation if a water-soluble coating is used. Resistive humidity sensors have significant temperature dependencies when installed in an environment with large (>10) temperature fluctuations. Simultaneous temperature compensation is incorporated for accuracy. The small size, low cost, interchangeability, and long-term stability make these resistive sensors suitable for use in control and display products for industrial, commercial, and residential applications.

One of the first mass-produced

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