

ARTISAN®
TECHNOLOGY GROUP

Your **definitive** source for quality pre-owned equipment.

Artisan Technology Group
(217) 352-9330 | sales@artisantg.com | artisantg.com

Full-service, independent repair center
with experienced engineers and technicians on staff.

We buy your excess, underutilized, and idle equipment
along with credit for buybacks and trade-ins.

Custom engineering
so your equipment works exactly as you specify.

- Critical and expedited services
- In stock / Ready-to-ship
- Leasing / Rentals / Demos
- ITAR-certified secure asset solutions

Expert team | Trust guarantee | 100% satisfaction

All trademarks, brand names, and brands appearing herein are the property of their respective owners.

Visit our website - *Click HERE*

RHK Technology Brief

APPLICATION • TUTORIAL • TECHNOLOGY

Low Current Imaging with RHK's STM Preamplifiers

George Lengel

RHK Technology, Troy, MI

New Edition - May 2014

RHK Technology

Imaging the Future of Nanoscience

www.rhk-tech.com

Design

RHK Technology provides a line of current-to-voltage preamplifiers that are unsurpassed in capability for all UHV STM applications. Many years of design went into optimizing their performance in applications where low current is necessary.

Early current-to-voltage converters used in STMs contained a simple design utilizing a single operational amplifier as shown in **Figure 1**. The gain is determined by the ratio of R1 and R2 and the bandwidth is determined by the product of R1 and the unavoidable stray capacitance of the tip along with the wire that carries the tunneling current from the tip to the input of the amplifier. As this capacitance is decreased, the bandwidth would increase for a fixed gain so careful design of the scan head was important and the length of wire was made as short as possible. It is desirable to have the bandwidth be as large as possible in order to scan the surface (and also acquire I-V spectroscopy) as fast as possible. This simple design has been abandoned by RHK to achieve industry leading performance that does not have anywhere near the noise levels given the same amount of bandwidth-limiting stray capacitance.

Another important consideration is that the actual amount of noise in the feedback circuit is almost entirely dominated by what is generated in the first stage amplifier where the actual current to voltage conversion is performed. Whatever signal/noise ratio is generated in this preamplifier will be the same regardless of all additional amplifiers because both the signal and the noise will be multiplied by the same gain factor. This is why so much effort has been exerted into the design of the first stage amplifiers that RHK Technology produces.

The line of amplifiers supplied by RHK are provided as two separate parts. There are two choices for the first stage amplifier.

The IVP 200 provides a fixed gain of 108 and a bandwidth of 50 kHz, while the IVP 300 provides a gain of 109 with a bandwidth of 5 kHz. The second stage amplifier has variable gain selected by jumper settings with choices of x1, x10, and x100. The bandwidth of this amplifier can also be changed by a jumper selection. Valid choices are 500 Hz, 1.5 kHz, 5 kHz, 15 kHz, 50 kHz, 150 kHz, and no filtering This second stage will be used along with the first stage to determine the overall gain of the feedback circuit. For the standard conversion that a 1 nanoamp current will produce a 1 volt signal, the required gain of 109 can be achieved two different ways: an IVP 200 can be used in conjunction with the IVP PGA set to a gain of 10 or the IVP 300 could be used with the second stage set to unity gain. An additional advantage to providing two stages of amplification is the IVP-PGA has adjustable potentiometers that can be used to calibrate the gain and offset of the feedback circuit which both can potentially drift over time. A simple calibration procedure can insure that the actual current is always measured without artifacts introduced by the circuit.

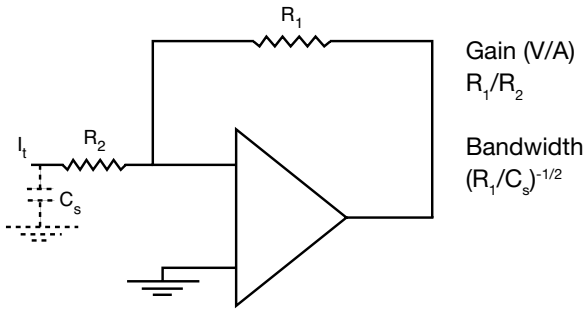


Figure 1: *Standard single stage STM preamplifier*

All of the preamplifiers are tested before shipment to ensure they achieve optimum performance. They are tested under two circumstances, the first is with no input capacitance to measure their best possible operating characteristics. Note this can never be achieved in any real microscope design because there will always be some non-zero capacitive

© 2014 RHK Technology, Inc. All rights reserved.

coupling between the tip and its environment. The second test is performed with 100 pF of input capacitance which represents about the worst environment any preamplifier could be placed in. This capacitance is equivalent to about one meter of high capacitance coaxial cable from the tip to the input of the amplifier. Therefore, these two tests represent the two practical limits of amplifier performance in an actual microscope.

Any real STM head will fall somewhere between these two extremes, except under rare circumstances where an STM is placed in a very large, low temperature cryostat which requires a very long wire from the tip to the outside environment.

The noise level of the output from the IVP PGA is measured and converted into an equivalent current noise, using the overall gain of the circuit. This measurement is repeated for each of the bandwidth settings of the second stage, and the values can then be plotted as a function of bandwidth to gain a complete picture of the amplifier's response for any working bandwidth that is desired.

These performance graphs represent the proper presentation of noise specifications. Many times a single noise number that sounds very impressive is specified, but without knowing the details of the testing procedure, it is meaningless. Almost any measurement will appear low when taken with a bandwidth of, for instance, 400 Hz. Having no input is the advantage presented by the amplifier being outside the vacuum system. This arrangement provides the simple option of disconnecting the external preamplifier when a high voltage or high current is applied to the tip as is commonly done for cleaning purposes. With an in situ amplifier, detaching the sensitive electronics from the tip is often difficult or impossible, and this limits the magnitude of the applied voltage to induce field emission cleaning when the tip is mounted in the scan head.

Performance

The real test of any preamplifier design is, of course, in the performance during actual data acquisition. Many materials that are of interest today require very low tunneling currents in order to avoid modifying the surface itself due to the presence of the tunneling tip. Some examples are self-assembled monolayers

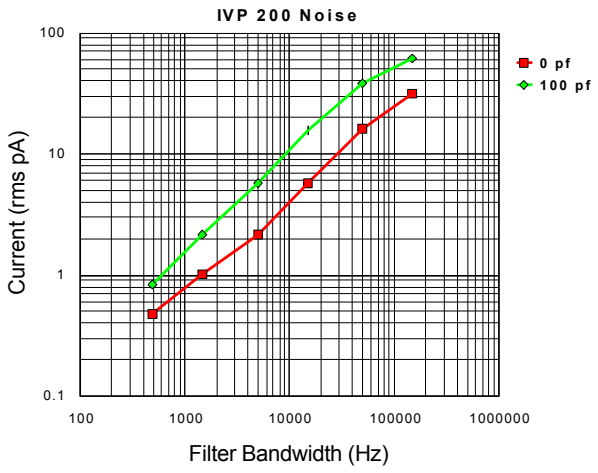


Figure 2: *Noise characteristics of IVP 200 preamplifier*

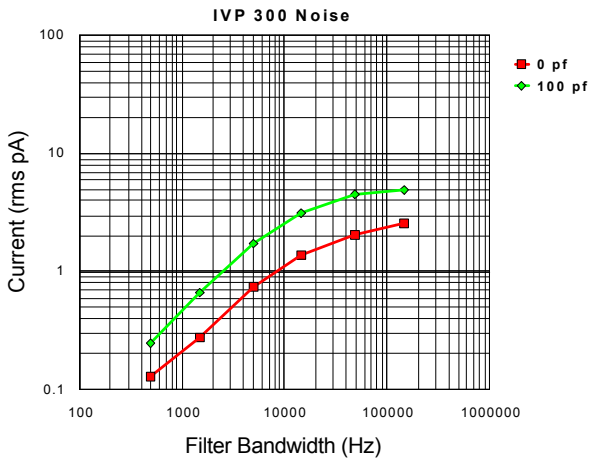


Figure 3: *Noise characteristics of IVP 300 preamplifier*

© 2014 RHK Technology, Inc. All rights reserved.

(SAMs) and various plastics; a sampling of images are presented in **Figures 4 and 5.**

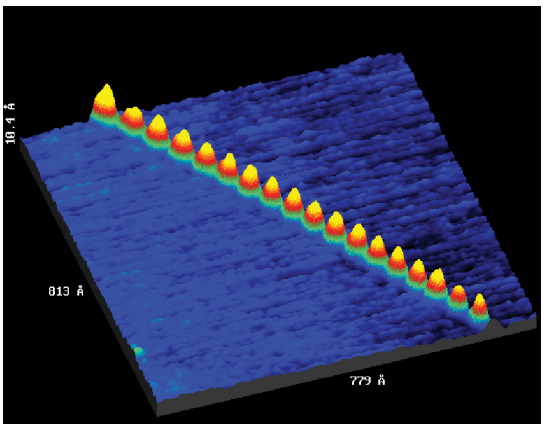
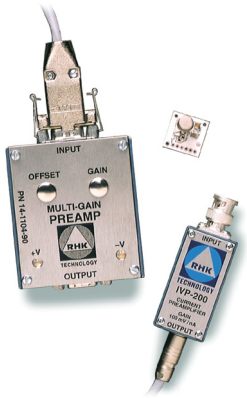


Figure 4: *Image of a polypropylene molecule on graphite acquired at 22 pA. Courtesy Richard Czerw & David Carroll, Clemson University.*

Specifications of RHK Preamplifiers

IVP-100
Gain: 10^7 (10mV/nA)
Bandwidth: 250 kHz
RMS Noise: 2 pA (2.2 pA) at 1.5 kHz and 0pF (100 pF) input capacitance (see graph)

IVP-200
Gain: 10^8 (100mV/nA)
Bandwidth: 30 kHz
RMS Noise: 1 pA (2.2 pA) at 1.5 kHz and 0pF (100 pF) input capacitance (see graph)



IVP-300
Gain: 10^9 (1V/nA)
Bandwidth: 5 kHz
RMS Noise: 0.3 pA (0.65 pA) at 1.5 kHz and 0 pF (100 pF) input capacitance (see graph)

IVP-PGA
Gain: x1, x10, x100 (selected by jumpers)
Bandwidth: 500 Hz, 1.5 kHz, 5 kHz, 15 kHz, 50 kHz, 150 kHz, None (selected by jumpers)
Inverting or non-inverting jumper selectable
User-accessible gain and offset adjustments

RHK Technology, Inc.
1050 East Maple Road, Troy, MI 48083
248-577-5426
www.rhk-tech.com | info@rhktech.com

Low Current Imaging of Self-Assembled Monolayers

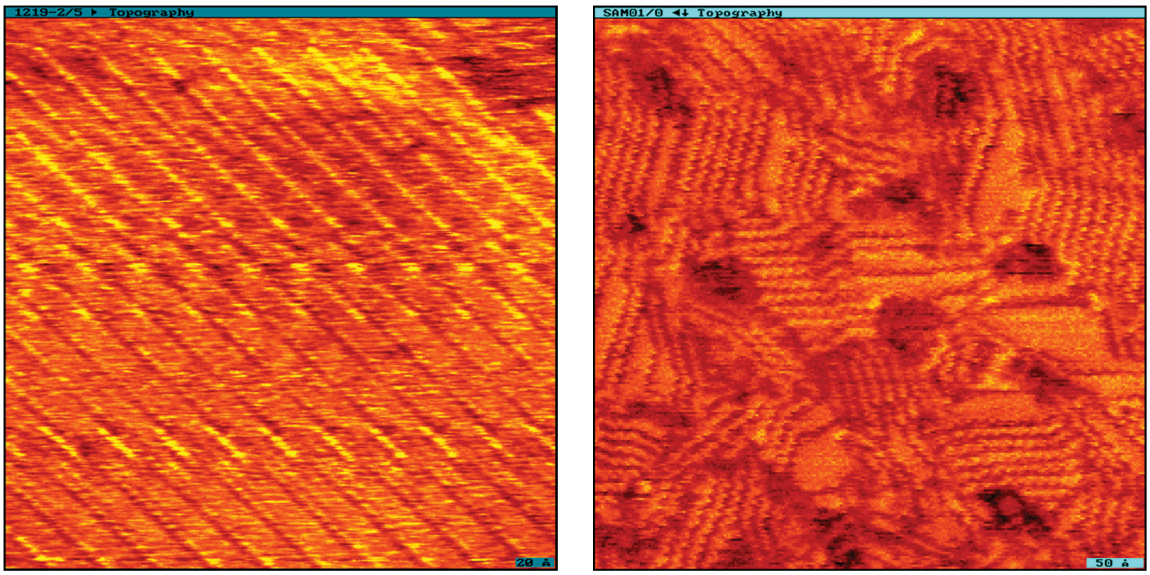


Figure 5: *(left) Image of an octanethiol on Gold (111) SAM acquired at 1 pA. Courtesy Yile Qian & Gang-yu Liu, Wayne State University. (right) Image of the pinstrip phase of an octanethiol on Gold (111) SAM acquired at 58 pA. Courtesy Lili Duan & Simon Garrett, Michigan State University.*

© 2014 RHK Technology, Inc. All rights reserved.

Artisan Technology Group is an independent supplier of quality pre-owned equipment

Gold-standard solutions

Extend the life of your critical industrial, commercial, and military systems with our superior service and support.

We buy equipment

Planning to upgrade your current equipment? Have surplus equipment taking up shelf space? We'll give it a new home.

Learn more!

Visit us at **artisantg.com** for more info on price quotes, drivers, technical specifications, manuals, and documentation.

Artisan Scientific Corporation dba Artisan Technology Group is not an affiliate, representative, or authorized distributor for any manufacturer listed herein.

We're here to make your life easier. How can we help you today?

(217) 352-9330 | sales@artisantg.com | artisantg.com

ARTISAN® TECHNOLOGY GROUP