

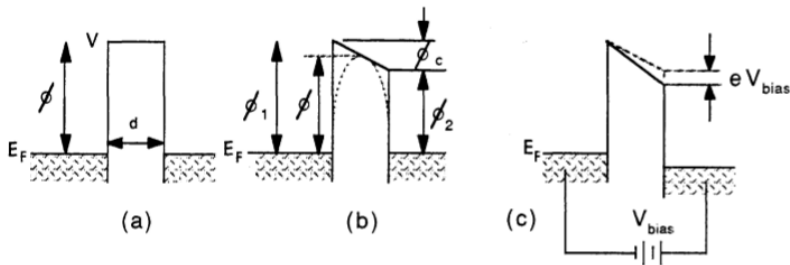
# Scanning Tunneling Microscope



Magyarkuti András

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2012. Május 3.

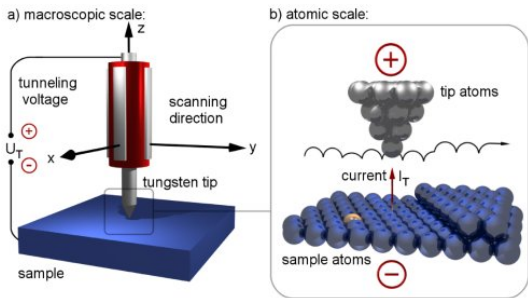


- ▶ (a): két azonos fém, közöttük vákuum,  $P \propto \text{Exp} \left\{ -\sqrt{\frac{8m}{h^2}} \Phi \cdot d \right\}$
- ▶ (b): két különböző fém, közöttük vákuum,  $P \propto \text{Exp} \left\{ -\sqrt{\frac{8m}{h^2}} (\Phi_1 + \Phi_2)/2 \cdot d \right\}$
- ▶ (c): feszültséget kapcsolunk rá  $\rightarrow I \propto V_b \cdot \text{Exp} \left\{ -A \cdot d \cdot \sqrt{\Phi} \right\}$ ,

$$A = 1.025 \text{ \AA}^{-1} eV^{-1/2}$$

[Roland Schaefer: Design and Construction of a Scanning Tunneling Microscope, 15213 (1989)]



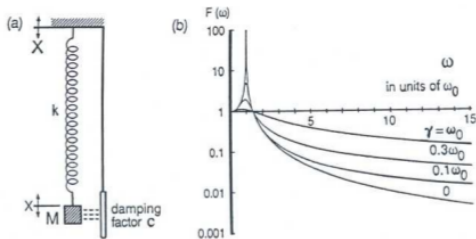


- ▶ Laterális felbontás:

$$\lambda = \sqrt{\frac{R+d}{A\sqrt{\Phi}}}, \quad \lambda \approx 5 \text{ \AA} \rightarrow R \leq 10 \text{ \AA}$$

- ▶ Hegyes tűre van szükség!
- ▶ Mechanikai stabilitás:
  - ▶ hőtágulás minimalizálása
  - ▶ hangszigetelés
  - ▶ rezgésmentesítés

# Rúgós rezgésmentesítés



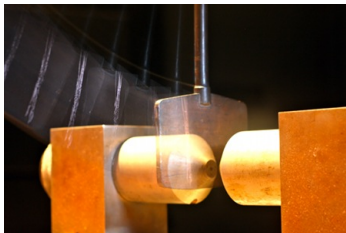
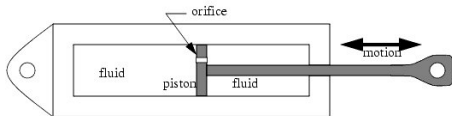
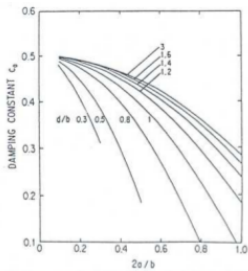
- ▶ Lineáris oszcillátor:  $\ddot{x}(t) + 2\gamma\dot{x}(t) + \omega_0^2x(t) = f(t)$
- ▶ Jósági tényező:  $Q = \frac{\omega}{2\gamma}$
- ▶ Rezonanciafrekvencia:  $\omega = \sqrt{\omega_0^2 - \gamma^2}$  - minél kisebb, annál előbb vág le az átviteli függvény
- ▶ Sajátfrekvencia:  $\omega_0 = \sqrt{\frac{k}{M}} = \sqrt{\frac{g}{\Delta L}}$

[Chen: Introduction to scanning tunneling microscopy]

## Viszkózus csillapítás

## Mágneses csillapítás

- ▶  $F = -C_0 \left( \frac{B^2 r^2 \pi t}{\rho} \right) v$
- ▶  $C_0$  - geometriától függő állandó:



[Chen: Introduction to scanning tunneling microscopy]

## 2 fokozatú rugós rezgésmentesítés

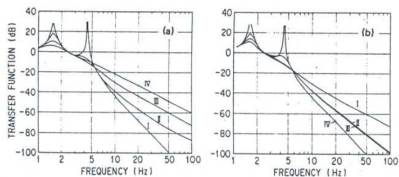
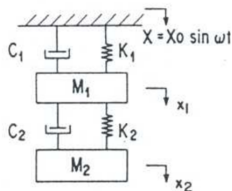


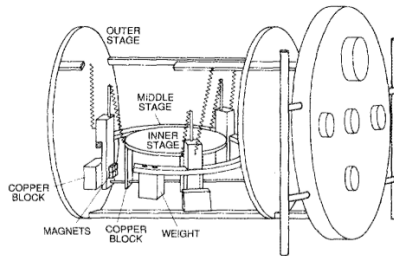
Fig. 10.5. Transfer functions for two-stage vibration isolation systems. Parameters for both (a) and (b):  $M_1=2.4$  Kg,  $M_2=2.9$  Kg,  $k_1=800$  N/m,  $k_2=700$  N/m. In (a), the damping stages are equally arranged,  $c_1 = c_2 = c$ . I,  $c=0$ . II,  $c=10$  Ns/m. III,  $c=20$  Ns/m. IV,  $c=50$  Ns/m. In (b), the effect of different arrangements of damping is illustrated. I,  $c_1 = c_2 = 20$  Ns/m. II,  $c_1=20$  Ns/m,  $c_2=0$ . III,  $c_1=0$ ,  $c_2=20$  Ns/m. IV,  $c_1 = c_2=0$ . (After Okano et al., 1987.)

- ▶  $M_1\ddot{x}_1 + c_1\dot{x}_1 + k_1x_1 + c_2(\dot{x}_1 - \dot{x}_2) + k(x_1 - x_2) = c_1\dot{X} + k_1X$
- $M_2\ddot{x}_2 + c_2(\dot{x}_2 - \dot{x}_1) + k(x_2 - x_1) = 0$
- ▶ Nagyobb csillapítás, mint az egy fokozatú esetben, UHV, alacsony hőmérsékletű mérések esetén célszerű használni.

[Chen: Introduction to scanning tunneling microscopy]

## 2 fokozatú rugós rezgésmentesítés

- ▶ Átlapoló rugók → kis méret, alacsony rezonancia frekvencia:

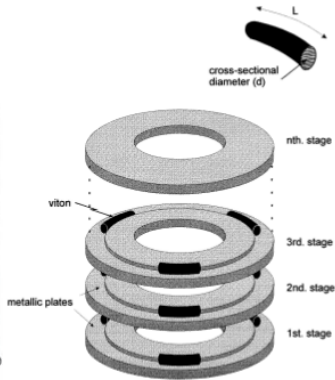
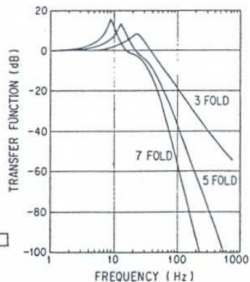
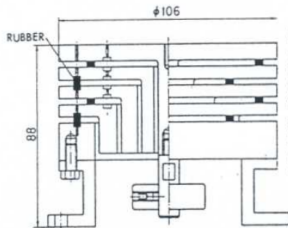


[Sang-il Park, C.F. Quate: Scanning tunneling microscope, Review of Scientific Instruments (1987)]



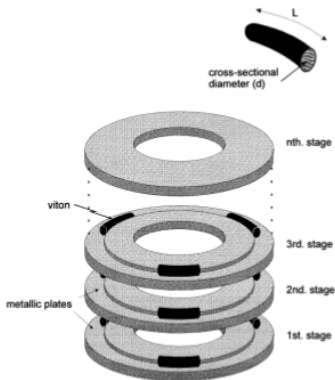
# Halmazott lemezekből álló rezgésmentesítés

- ▶ kompakt méret
- ▶ nem szükséges külön csillapítás
- ▶ magasabb frekvenciákat szűri ki jól



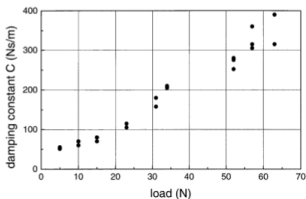
[Chen: Introduction to scanning tunneling microscopy]

# Halmazott lemezekből álló rezgésmentesítés



- ▶ Terhelést növelve nő a csillapítási konstans:

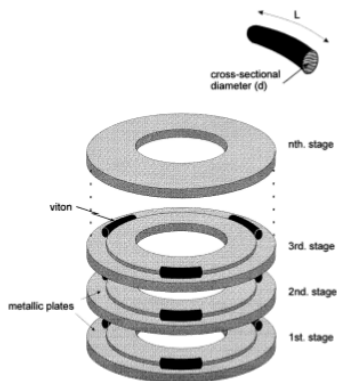
$$F = C\dot{x}$$



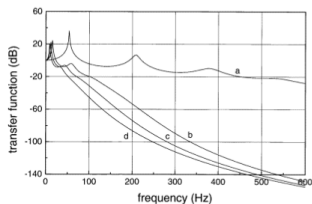
- ▶ 1 lemez,  $d = 4.7$  mm,  $L = 5$  mm

[A.I.Oliva et al.: Low- and high-frequency vibration isolation for scanning probe microscopy, Meas.Sci.Tech. 9 (1998)]

# Halmazott lemezekből álló rezgésmentesítés



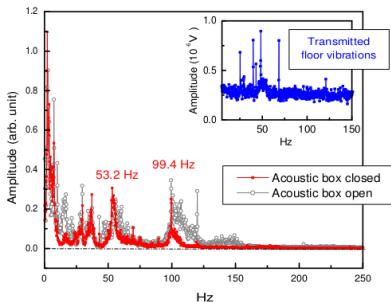
▶ Átvitel különböző paraméterű gumigyűrűk esetén:



**Figure 8.** The transfer function of the last stage of a seven-stage VIS system obtained with a viton diameter  $d = 4.7$  mm for four viton lengths. The first six masses are equal to 0.208 kg and  $M_7 = 1.5$  kg. Curve (a) corresponds to an entire 'O' ring ( $L = 390$  mm) used between plates. Other curves used the following viton lengths ( $L$ ): (b) 20 mm, (c) 10 mm and (d) 5 mm.  $K$  values were (a) 1516400 N m<sup>-1</sup>, (b) 123300 N m<sup>-1</sup>, (c) 71800 N m<sup>-1</sup> and (d) 42000 N m<sup>-1</sup>. A typical value of  $C = 80$  N s m<sup>-1</sup> was taken for all curves.

[A.I.Oliva et al.: Low- and high-frequency vibration isolation for scanning probe microscopy, Meas.Sci.Tech. 9 (1998)]

Hangszigetelő doboz vizsgálata:



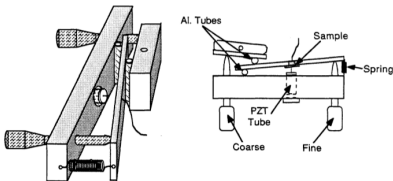
- ▶ A doboz lényegesen lecsökkenti a zajokat, 100 Hz felett gyakorlatilag teljesen szűr.

[Chen, Ching-Tzu: Scanning tunneling spectroscopy studies of high-temperature cuprate superconductors, Ph.D., Caltech (2006)]

- ▶ Tű-minta távolság: mm  $\rightarrow$  4 - 6 Å

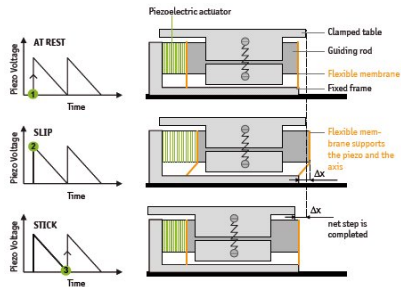
- ▶ Finommechanika:

[Roland Schaefer: Design and Construction of a Scanning Tunneling Microscope, 15213 (1989)]

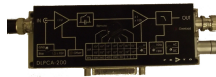


- ▶ Inerciális piezo:

[<http://www.attocube.com/nanoPOSITIONING>]



- ▶ Áramerősítő



- ▶ Piezo tápegység

- ▶ Range  $\approx 100$  V
- ▶ zaj  $< mV$



- ▶ Adatgyűjtő/szabályozó elektronika



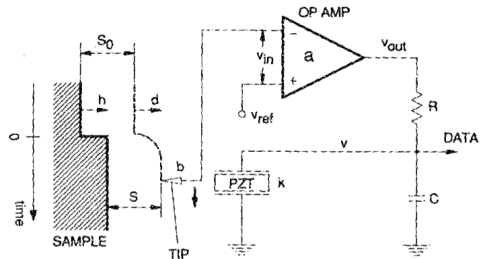


$$d(t) = kv(t - \tau)$$

$$\Delta s(t) = d(t) - h(t)$$

$$v_{in}(t) = b\Delta s(t)$$

$$v_{out}(t) = -av_{in}(t) = -ab\Delta s(t)$$



$$v(t) = \frac{Q}{C} = \frac{1}{C} \int_0^t I(t') dt' = \frac{1}{RC} \int_0^t [v_{out}(t') - v(t')] dt'$$

$$\frac{dv(t)}{dt} = \frac{1}{RC} [v_{out}(t) - v(t)] = -\frac{1}{RC} v(t) - \frac{abk}{RC} v(t - \tau) + \frac{ab}{RC} h(t)$$

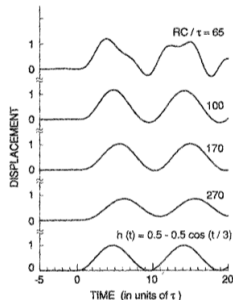
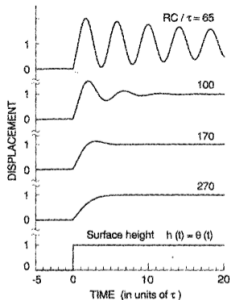
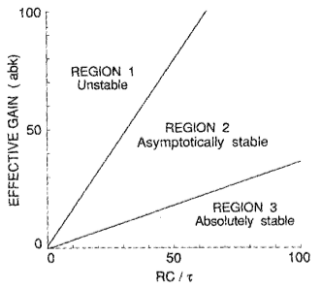
[Sang-il Park, C.F. Quate: Scanning tunneling microscope, Review of Scientific Instruments (1987)]



$$\frac{dv(t)}{dt} = -\frac{1}{RC}v(t) - \frac{abk}{RC}v(t - \tau) + \frac{ab}{RC}h(t)$$

Legyen  $h(t)$  lépcsőfüggvény, az állandósult megoldás:

- ▶  $\frac{dv(t)}{dt} = 0, v(t) = v(t - \tau) \rightarrow v(t) = \frac{ab}{1+abk}, \Delta s(t) = \frac{-1}{1+abk}$
- ▶  $abk > 100$  esetén nem okoz problémát
- ▶ Stabilitás:  $abk < \frac{RC}{\tau} e^{-(1+\tau/RC)}$



[Sang-il Park, C.F. Quate: Scanning tunneling microscope, Review of Scientific Instruments (1987)]

Köszönöm a figyelmet!