Glass Plates Noise Transmission Suppression By Means of Distributed Piezoelectric Composite Actuators Shunted By an Active Circuit

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Introduction: Glass windows or facades represent a virtual sound source for buildings interior. Because of their „large thin plate“ geometry, it is very easy to make them vibrate by action of incident acoustic pressure wave. Therefore, non-negligible part of the wave is transmitted through the window (Fig.1a). We propose a method based on the change of mechanical properties of the glass using flexible **piezoelectric Macro Fiber Composite** (MFC) actuators [1] distributed on the glass surface and shunted by **active circuits with Negative Capacitance** (NC) [2] which can effectively control elastic properties of the piezoelectric material (Fig.1b). We assume the method resulting in:

- increase of bending stiffness and Young's modulus of the composite "plate + MFC"

→ **decrease of the amplitude of vibrations**

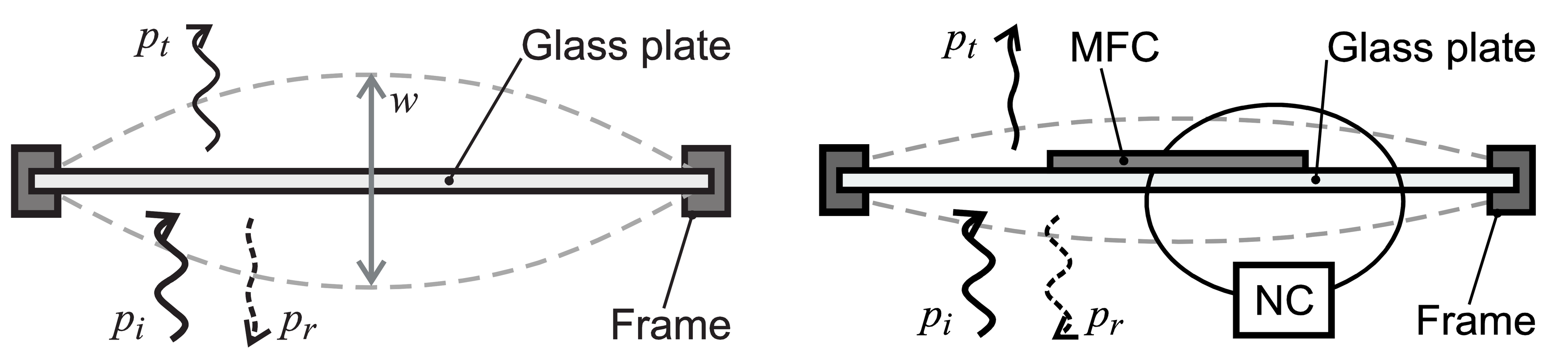

Figure 1. a) Acoustic pressure wave transmitted through the window; b) MFC actuator stiffened by NC circuit, it results in the increase of the glass plate bending stiffness

Computational Method: Sound shielding efficiency is measured by **acoustic Transmission Loss** (TL). It can be expressed using specific acoustic impedance Z_w of the glass plate:

$$TL = 20\log\left|1+\frac{Z_w}{2Z_{air}}\right|; \qquad Z_w(\omega)\approx\frac{\Delta P(\omega)}{i\omega W(\omega)}$$

Physics: Acoustic – structure interaction (frequency analysis → 10 – 2000 Hz) governed by the equation of motion

$$2\rho\omega^2\mathbf{u}-\nabla\cdot\mathbf{C}\left[(\nabla\mathbf{u})^T+\nabla\mathbf{u}\right]=0$$

and Helmholtz's equation

$$-\frac{\omega^2 p}{\rho_{air}c^2}+\nabla\cdot\left(-\frac{1}{\rho_{air}}\nabla p\right)=0$$

ΔP… acoustic pressure difference at 1cm under and above glass surface
W … ampl. of vibrations at glass midpoint
$\mathbf{u}$ … displacement vector
p … acoustic pressure distribution
$\mathbf{C}$ … elastic moduli tensor

1. Results step: Freq. dependence of **effective elastic material parameters** (Young's and shear moduli, $Y_{ii}(f)$ and $G_{ij}(f)$) of the piezoelectric composite which is shunted by NC circuit (Fig.2)
→ **max values at single frequency f_0**

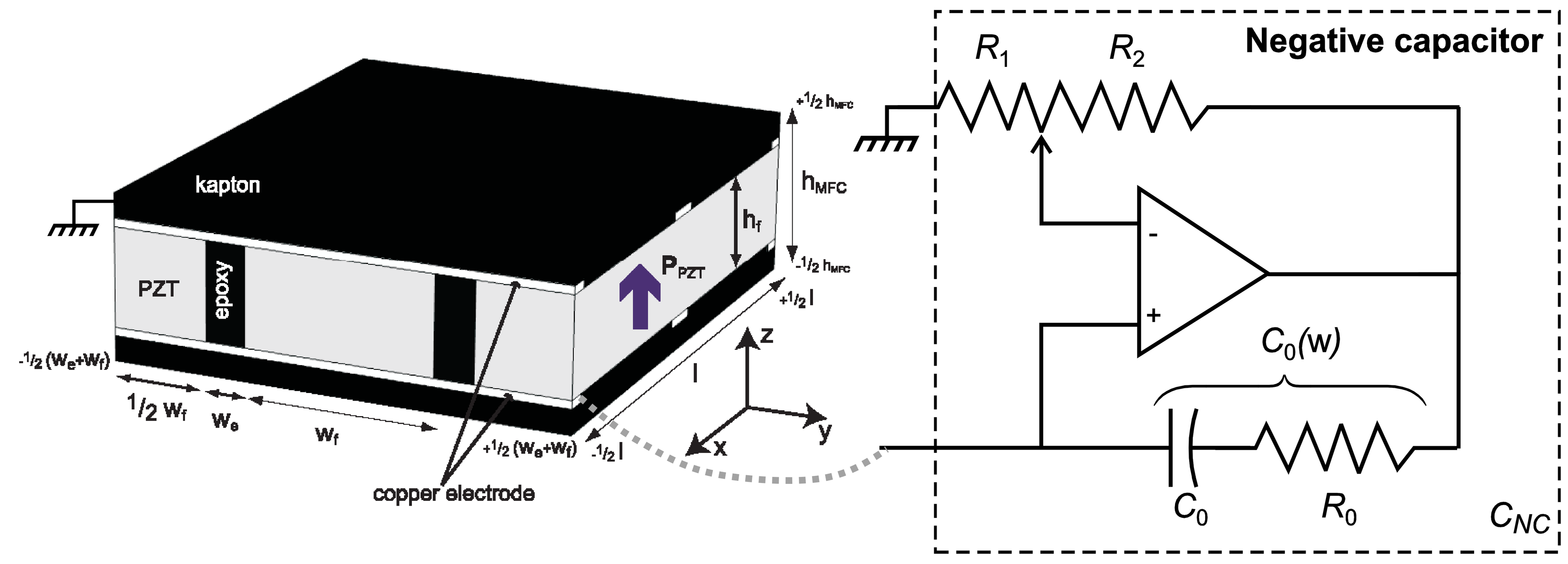

Figure 2. MFC actuator geometry shunted by the active electronic NC circuit working as impedance invertor

2. Results step: Applying calculated values of Y_{ii} and G_{ij} of MFC patches distributed on the glass surface and performing the frequency acoustic – structure analysis which is made as a case study for the geometry of the glass plate ((i) **flat**; (ii) **curved**) and elastic parameters of MFC actuators ((iii) **controlled by the NC**; (iv) **no control – free electrodes**)).

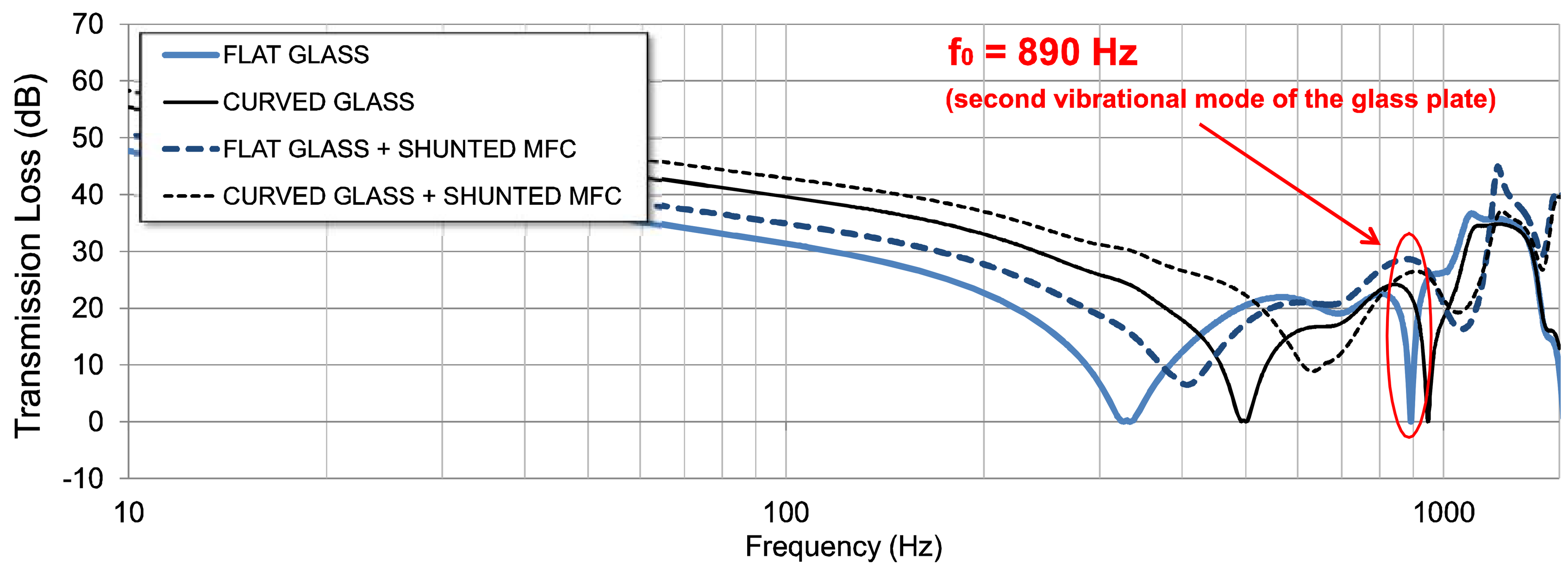

Figure 3. Acoustic TL(f) through the glass plate

Conclusions: Simulations show (Fig.3) that it is possible to increase the TL by about 25dB at both first vibrational mode due to the curved geometry and at the second vibrational mode due to the effect of properly adjusted shunted NC circuit.

References:

1. Smart material corp. (2000-2012). URL http://www.smart-material.com.
2. M. Date et al.,Electrically controlled elasticity utilizing piezoelectric coupling, *J of App Phys*, 87(2), 863-868, (2000).