Design and Analysis of Micro-tweezers with Alumina as gripper using COMSOL Multiphysics

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CONTENTS

INTRODUCTION

- **Micro tweezers** - widely investigated structure
- **Applications**
  - Micro fluidics technology
  - Micro surgery
  - Tissue engineering
  - Micro-assembly of microelectronics,
  - Communication devices and precision machining.
- **Types**
  - Electrostatic actuation
  - **Thermal actuation**

There is a great demand for micro grippers or tweezers with a controlled grasping force and accuracy

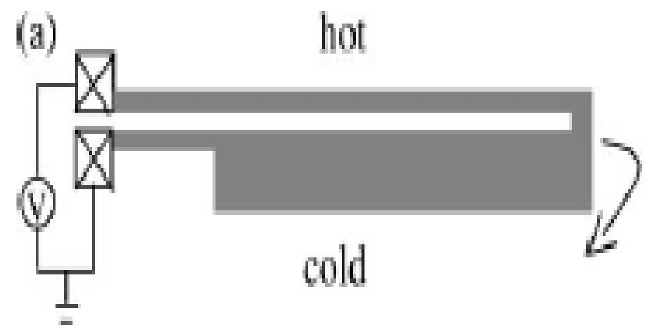
ELECTRO THERMAL ACTUATION

Thermal actuators deliver a
- Large force
- Large opening displacements

But operates at
- High current
- High temperatures

Joule Heating

Actuation:
Fig 1 (a) Arms in series - the structure tend to bend toward the wide arms.
Fig 1 (b) Arms in parallel – the structure tend to bend towards the narrow arm



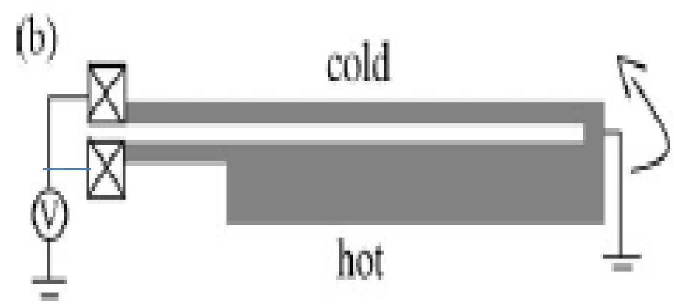


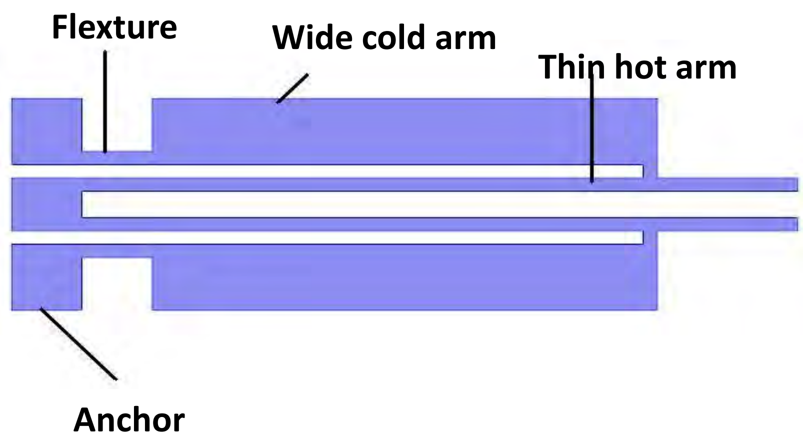
Fig 1 Courtesy : Nilesh D Mankame and G.K. Ananthasuresh (2001)

MICRO TWEEZERS STRUCTURE

The structure consists of a pair of lateral thermal actuators with hot arms facing each other.

When current passes, the thin arms get heated more than the wide arms and leads to expansion of the hot arms.

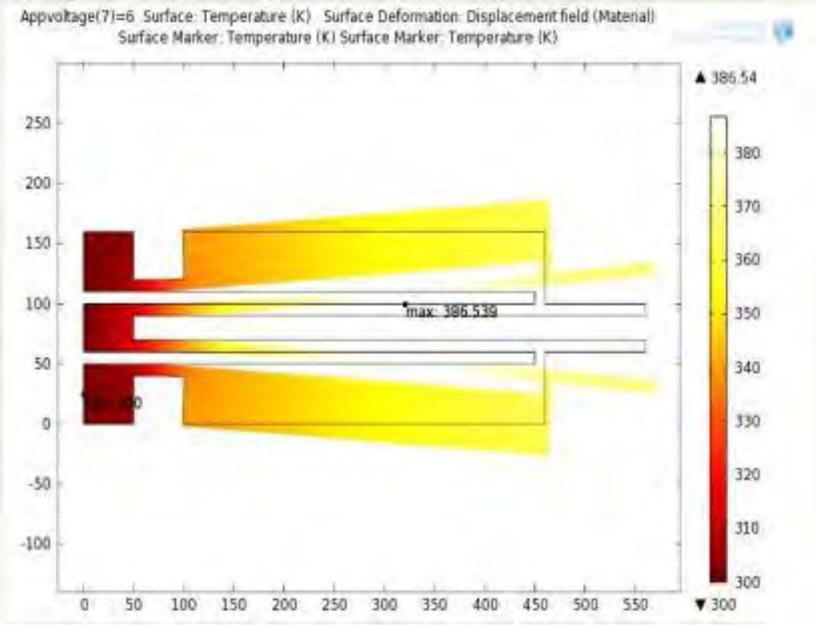
Deflection is affected by,
- widths of the hinge and hot arms
- Gap between the hot and cold arms

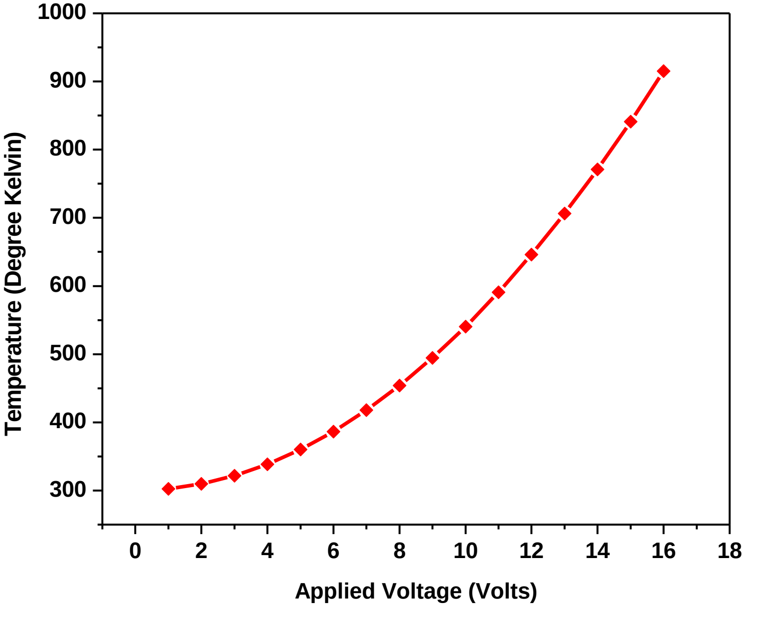


Smaller gap and narrower beam leads to higher deflection

TEMPERATURE DISTRIBUTION

- Temperature Vs applied voltage

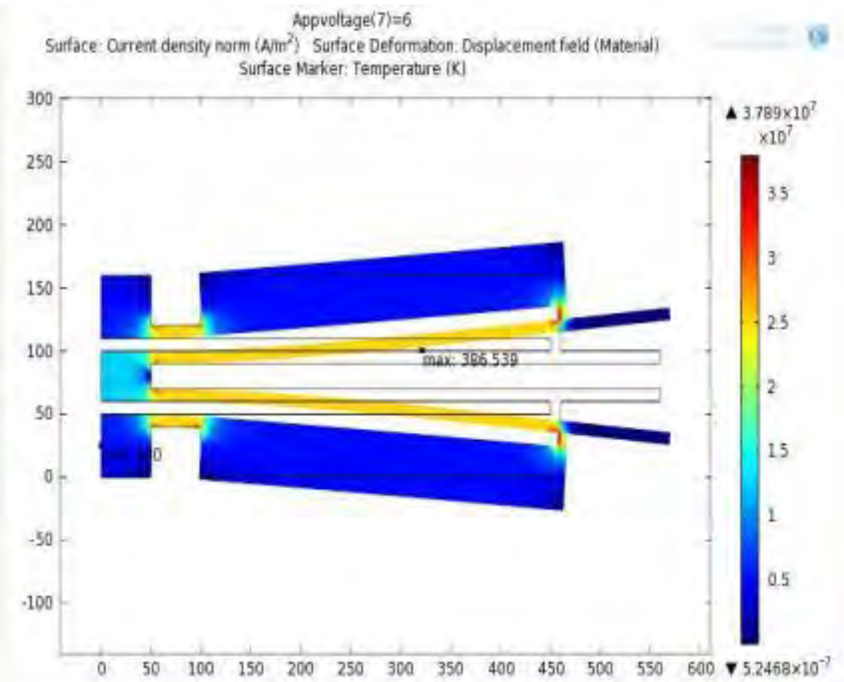


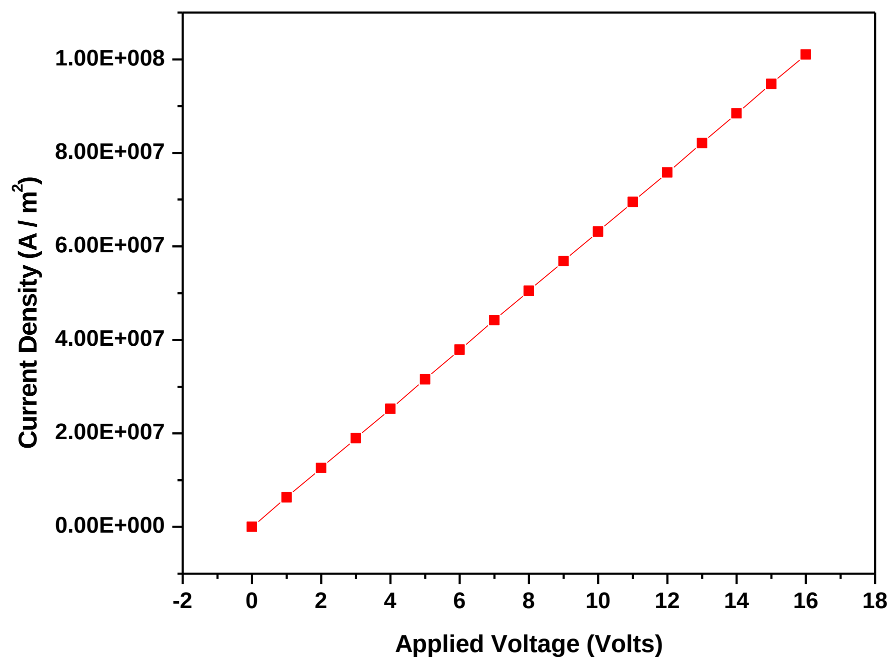


Thin arms get heated up more than the wide arms.
Maximum temperature falls at the center of the hot arm.
The maximum temperature increases exponentially with the applied voltage

CURRENT DENSITY

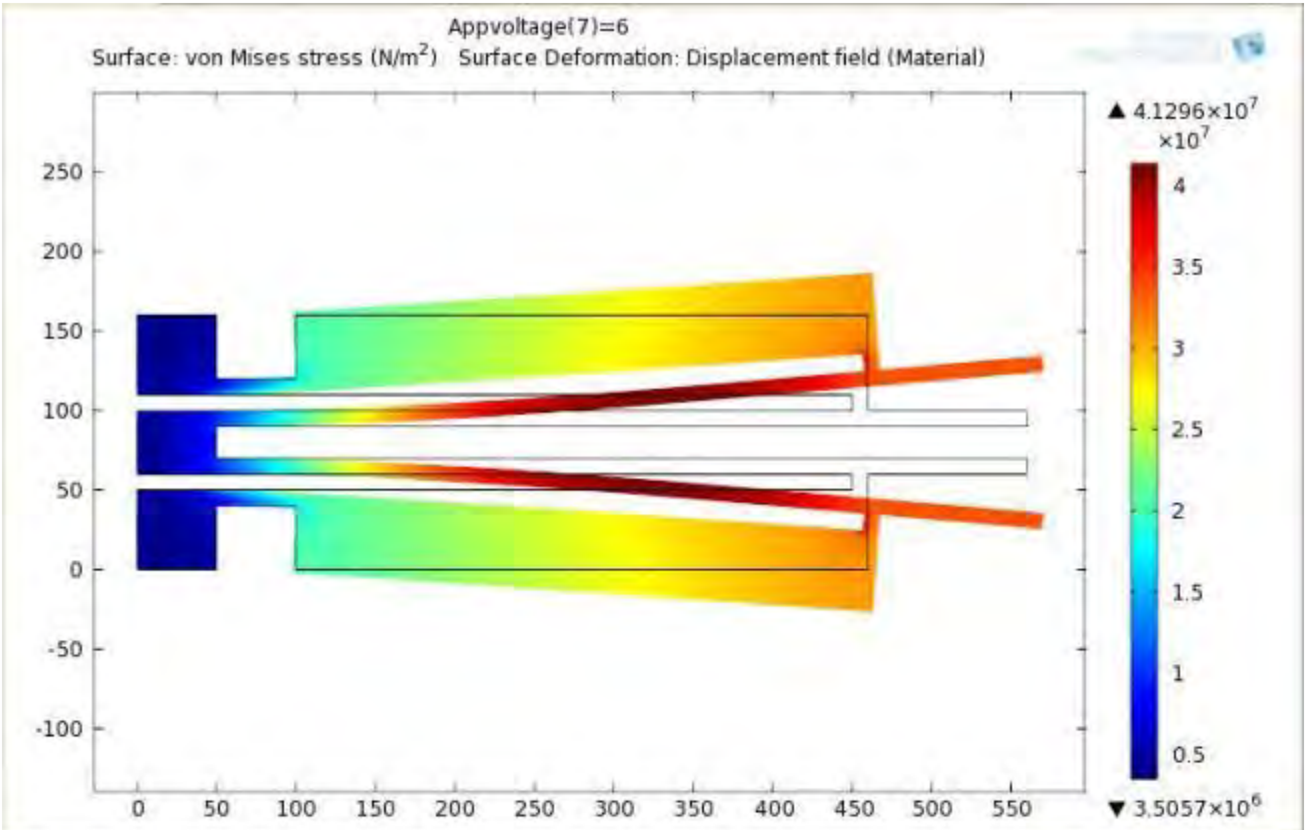
- Current Density Vs Applied Voltage





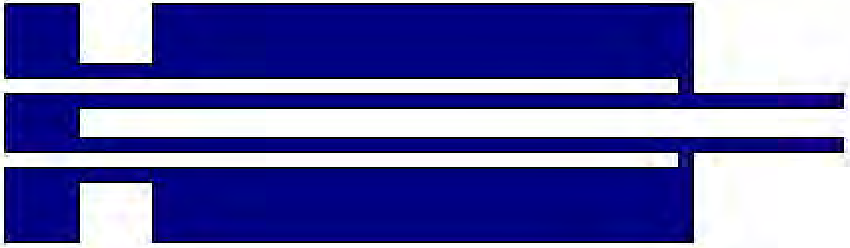
- **Current density is more in the hot arms than in the cold arms**
- **Current density at the center of the hot arm is measured with the applied voltage**
- **Current density increases linearly with the applied voltage**

STRESS DISTRIBUTION



The stress at the hot arms and at the gripper tips are higher (35-40 MPa)
The higher stress will lead to breaking / damaging of the device

Animation

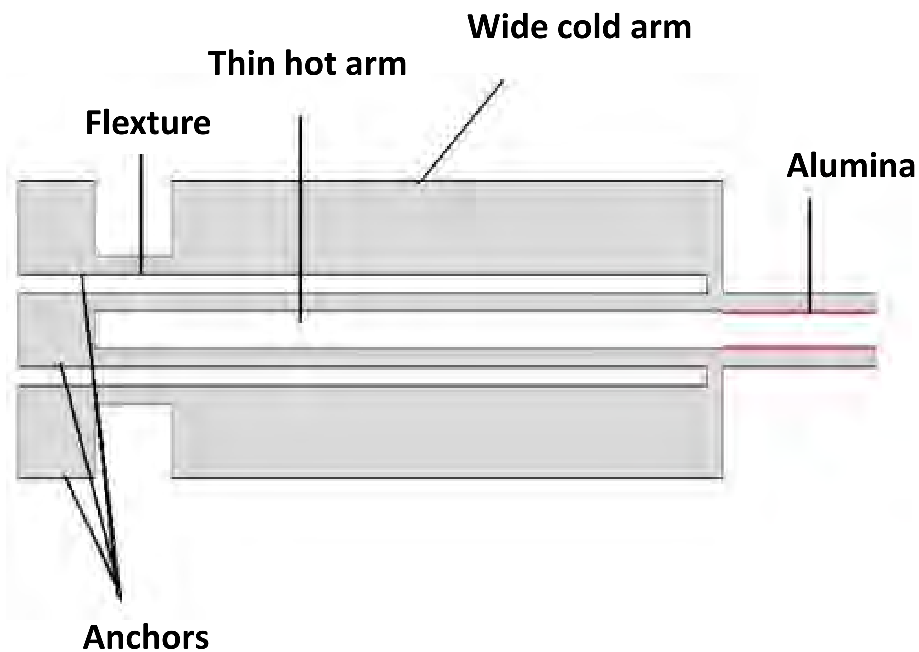


ALUMINA GRIPPERS

- Ceramics are the right material to use at high temperatures and to get good grip in the tweezers
- Good mechanical strength and low chemical reactivity
- Silicon grippers are too fragile and smoother
- Alumina is the strongest and stiffest of the oxide ceramics
- Melting point of Alumina is 2072 °C

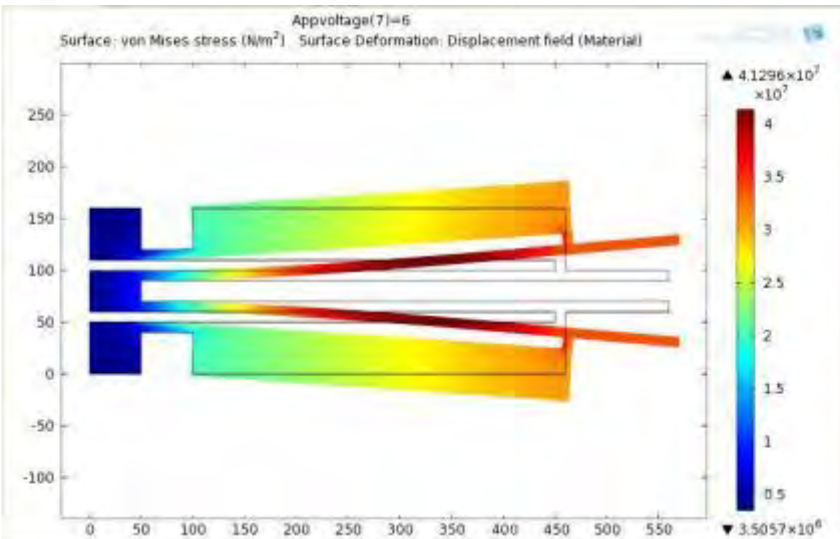
We have used Alumina at the tip of the gripper structure

ALUMINA GRIPPERS

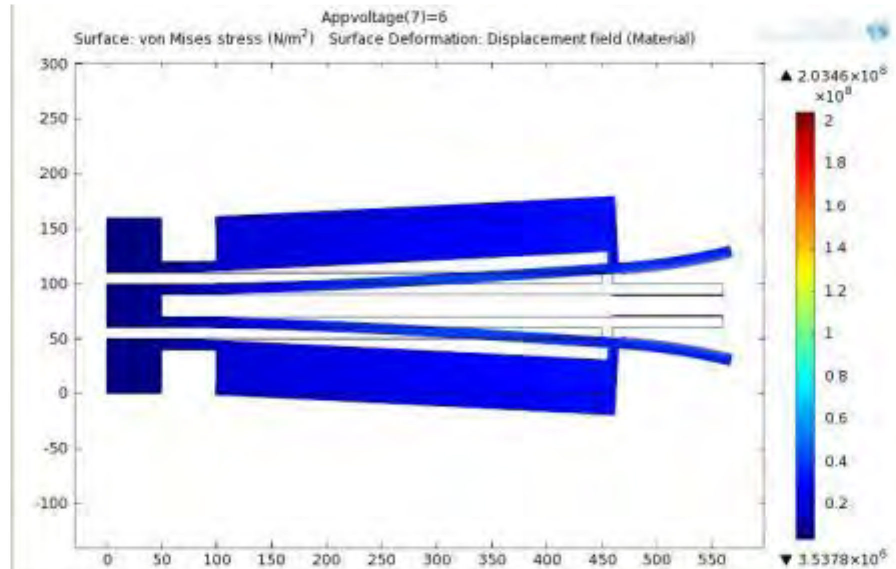


STRESS DISTRIBUTION

Silicon gripper

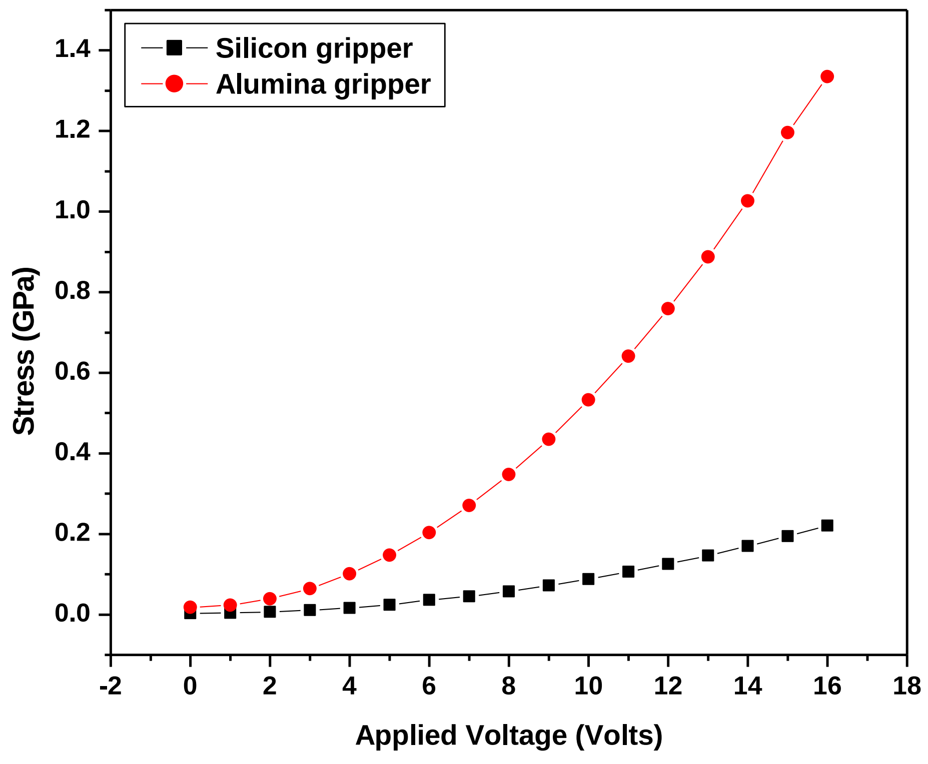


Alumina gripper



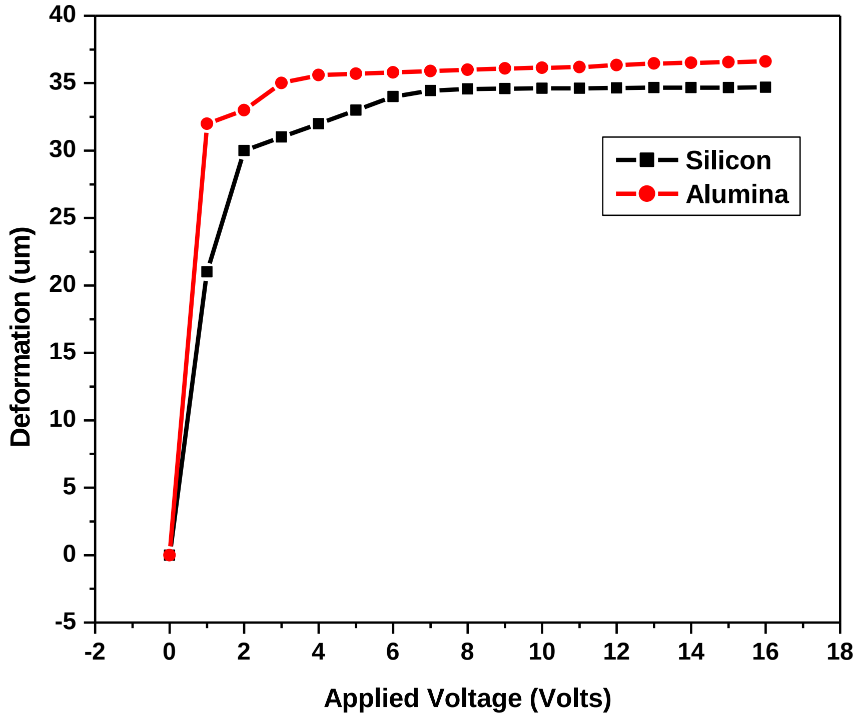
- **Stress distribution seems to be uniform in the alumina gripper.**
- **It is found that stress is very high at the alumina due to residual stress.**

STRESS VERSUS APPLIED VOLTAGE



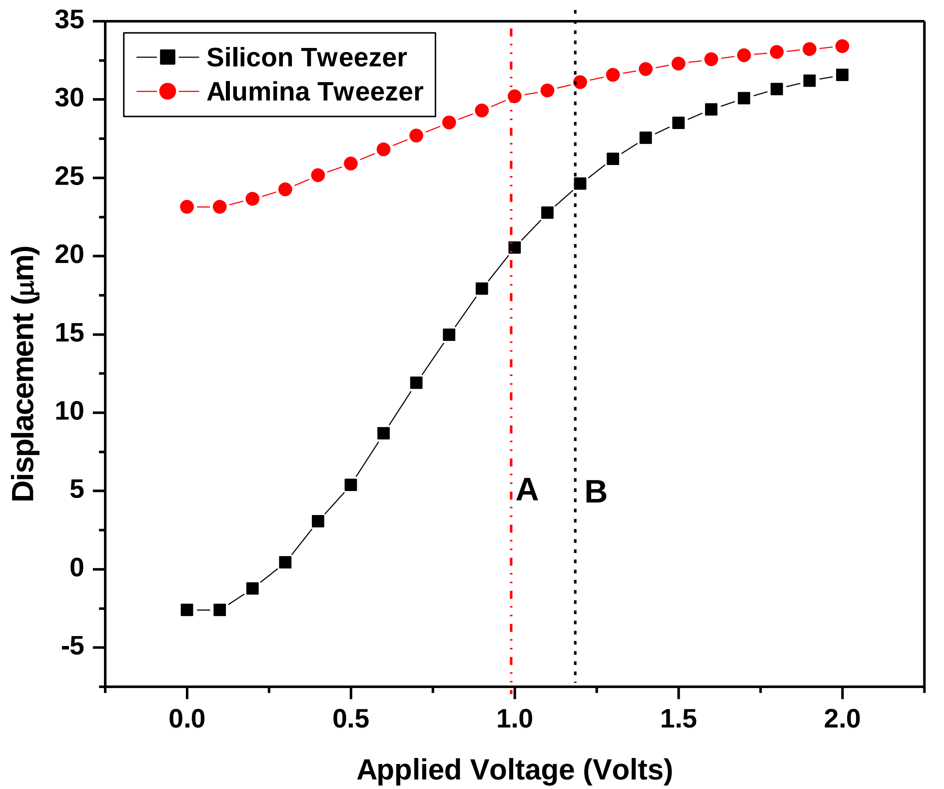
- Stress at the alumina gripper tip is higher than that of silicon gripper tip
- Alumina tips do not change the stress on the structure.

DISPLACEMENT WITH APPLIED VOLTAGE



- The linear range of operation for silicon is 0 -2 V
- The linear range of operation for alumina is 0-1 V

DISPLACEMENT AT LOW VOLTAGES



Displacement is higher in alumina than silicon

Higher displacement at 0V due to high residual stress

Sensitivity and range of operation are lower in Alumina grippers

PROBLEMS

- **Fabrication problems:**
  - Alumina can be deposited by thermal evaporation of Aluminium in the oxygen ambient.
  - But deposition and patterning of Alumina at the sides of the gripper tips are not possible
- **Design Modifications:**
  - Structure has to be modified to reduce the stress
  - Design has to be modified to extend the range of operation and sensitivity

SUMMARY

- Structure of Micro tweezers is designed
- Analysis of Micro tweezers with temperature, current density, displacement and stress are carried out
- Silicon gripper tips and Alumina gripper tips were studied
- Alumina gripper structure has to be modified to improve the performance

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Thank you