

According direction of
tensile load, which is
shown



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According to the stress-strain curves (Fig. 4b), the thin film which deposited at 0.3 Pa (sample S2) has the highest strength and toughness because of its unique microstructure (nano-crystalline) (Fig. 2b). While the thin film deposited at 0.

1Pa (sample S1) shows low strength. According to XRD patterns, the structure of all crystallized thin films is austenitic except the thin film deposited at 0.1 Pa, which displayed martensitic structure. The deformation of the Ni-rich NiTi thin films proceeded through the following four stages 38-39: elastic deformation of the parent phase, stress-induced martensitic transformation (austenite) or rearrangement of martensite twins, elastic and plastic deformation of the martensite phase.

After elastic deformation of the parent phase, the second stage of the stress-strain curve corresponds to stress-induced martensitic transformation that leads to decrease the slope (plateau region) of the curves in samples S2, S3 and S4, while in the martensitic sample (S1), the low plateau results from the stress-induced growth of one martensite orientation. The sputter-deposited thin film at 0.3 Pa shows high yield stress (above 1.6 GPa) because of nano-grain size and are also largely attributed to the fine precipitates of Ti_3Ni_4 in Ni-rich thin films 40-42.

The cracks propagated across the width of the film. The direction of crack propagation was almost perpendicular to the direction of tensile load, which is shown in Fig. 5a. Crack growth or delamination of the film can be explained as a creating a new surface at the expense of the elastic energy release of structure based on linear elastic fracture mechanics. There are

three types of loading that a crack or delamination can experience; First mode (I) relates to the applied principal load that is normal to the crack plane and is likely to open the crack. The second mode (II) relates to surface shear loading and has a tendency to slide one crack surface with respect to the other.

The third mode (III) corresponds to out-of-plane shear. A cracked or delaminated body can be loaded at any one of these modes, or a combination of two or three modes 43. A weak bonded thin film/substrate enables less of a constraint on the film. Slight strain localization because of a surface perturbation or film imperfection can easily induce local delamination and the two processes, e. g., strain localization and de-bonding facilitate each other thereafter, resulting in micro-cracks and final rupture of the film.

The SEM images of the breaking surface of the NiTi thin film deposited at sputtering pressure of 0.3 Pa (sample S2) shows a ductile fracture with nano-dimples and dense microstructure (Fig. 5b).

Furthermore, figure 5b shows clearly this thin film possesses enough ductility and strength for practical application. This dramatic enhancement is a direct result of the film's nanostructure. The thin films deposited at higher sputtering pressure (samples S3 and S4) display lower strength and ductility due to the existence of the micro-cracks in the as-deposited thin film. The sample S4, which deposited at the highest sputtering pressure (sample S4) shows the least strength (about 250 MPa) because of the existence of continues micro-cracks network in its structure (Fig.

5c). This micro-crack network leads to rupture of the thin film at low stress.

This fracture is like de-cohesion that is illustrated clearly in Fig 5d.