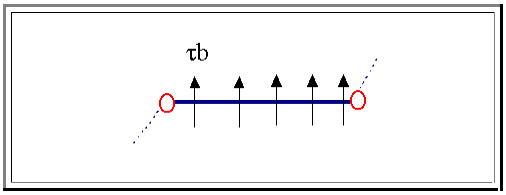
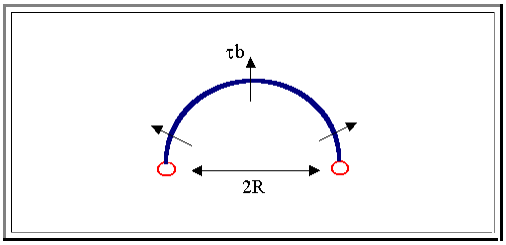
5.3.2 Generation of Dislocations

Whereas we now learned a little bit about the complications that may occur when dislocations move, we first must *have* some dislocations before plastic deformation can happen. In other words: We need **mechanisms** that **generate dislocations** in the first place!

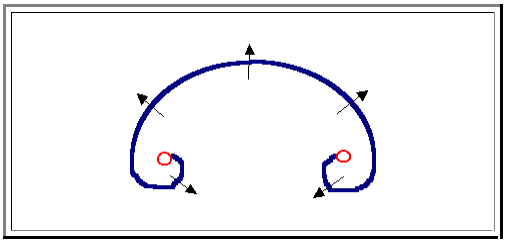
- Of course, dislocations can just be generated at the surface of the crystal; the simple pictures showing plastic deformation by an (edge) dislocation mechanism give an idea how this may happen. But more important are mechanisms that generate dislocations in the bulk of a crystal. The most important mechanism is the **Frank-Read mechanism** shown below.



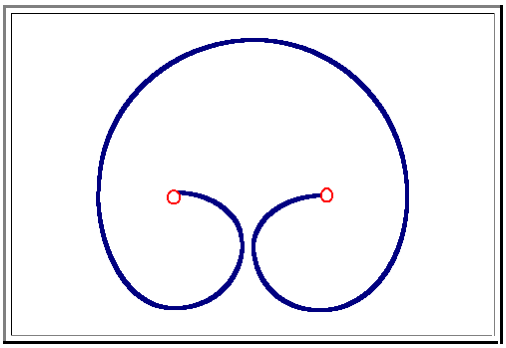
- We have a segment of dislocation firmly anchored at two points (red circles). The force $\boldsymbol{F = b \cdot \tau_{res}}$ is shown by a sequence of arrows



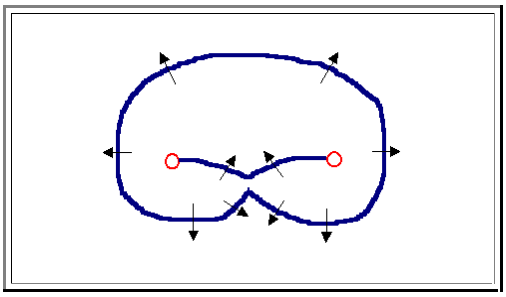
- The dislocation segment responds to the force by bowing out. If the force is large enough, the critical configuration of a semicircle may be reached. This requires a maximum shear stress of
  $\boldsymbol{\tau_{max} = Gb/R}$



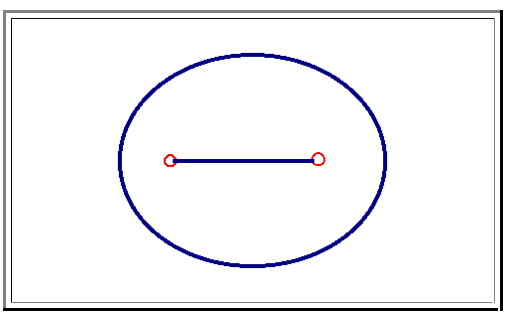
- If the shear stress is higher than $\boldsymbol{Gb/R}$, the radius of curvature is too small to stop further bowing out. The dislocation is unstable and the following process now proceeds automatically and quickly.



- The two segments shortly before they touch. Since the two line vectors at the point of contact have opposite signs (or, if you only look at the two parts almost touching: the Burgers vectors have different signs for the same line vectors), the segments in contact will annihilate each other.



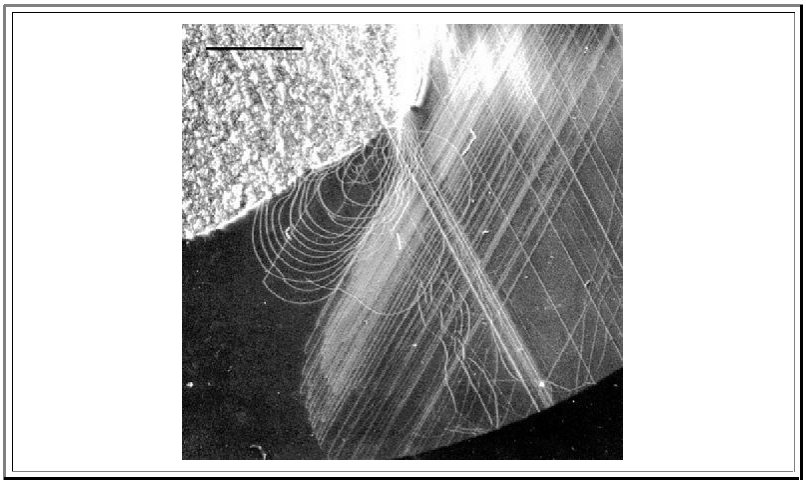
- The configuration shown is what you have immediately after contact; it is totally unstable (think of the rubber band model!). It will immediately form a straight segment and a "nice" dislocation loop which will expand under the influence of the resolved shear stress.
- The regained old segment will immediately start to go through the whole process again, and again, and again, ... - as long as the force exists. A whole sequence of nested dislocation loops will be produced.



- Stable configuration after the process. The loop is free to move, i.e. grow much larger under the applied stress. It will encounter other dislocations, form knots and become part of a network. The next loop will follow and so on - as long as there is enough shear stress.

The Frank-Read process, although looking a bit odd, will occur many times under sufficient load. It can produce any density of dislocations in short times, because the newly formed dislocations will move, become anchored at some points, and start to generate Frank-Read loops, too.

- Of course, Frank-Read dislocation sources can also be stopped - e.g. by cutting through the generating dislocation by another dislocation. We thus will have a certain finite dislocation density under certain external conditions. It may, however, depend on many parameters, including the history of the material.
- Some kind of Frank-Read mechanism may also operate from irregularities on the surface (external or internal), an example of such a source is shown in the X-ray topography below.



- This picture comes from the work of K.B. Kostin (a former student in Kiel) together with many others in St. Petersburg. It is a result of investigations into "wafer bonding", where to **Si** wafers are placed on top of each other and "bonded", so that a single piece of **Si** results - with a grain boundary in between. The mottled area in the upper left hand corner shows such a bonded structure, whereas the dark area containing the dislocations as white lines, remained unbonded.
- Dislocations were introduced into one of the wafers and one point on the edge of the bonded area acted as a Frank-Read source. The nested series of dislocation loops is splendidly visible. There are also lots of straight dislocations which have moved considerable distances from their point of origin.

How else can we make dislocations? Suffice it to mention that there are variants of the basic Frank-Read mechanism, too and some more exotic mechanisms. We will not go into details; the important part is that it is generally an easy process to generate many dislocations provided you already have a few to start with.

- Last but not least: "*Frank*" is not the first name of Mr. *Read* - as ever so often, two independent persons figured out this mechanism at practically the same time (in **1950**) - look up the link for details.